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AERONAUTIC
MEETING NUMBER

SEPTEMBER 1929

WATSON
RUBBER FLOW
STABILATORS

They WORK . . .
and don't CHANGE

Can you say the same
for what you now use?

S. A. E. JOURNAL

CONTENTS

Reorganization Plan Approved by Members

Council Officially Lists Eight Professional Activities and Names Committeemen for Remainder of Administrative Year

THE amendments to the Constitution set forth in the letter-ballot form distributed among the voting members last July have been adopted. The total number of votes cast was 743, all of these being in favor of the proposed Constitutional changes except that from 7 to 9 members were opposed to one or another of the specific provisions. The report of the tellers, A. L. Beall, David Beecroft and C. B. Whittelsey, Jr., was transmitted to the members and to the Council.

This concludes, so far as putting the new plan into effect is concerned, the momentous discussion that has been had for several years as to the best procedure for maintaining the activities of the Society in furtherance of the welfare of the industry as well as of the Society and its members individually. In general, the method of electing the Society officers and Council members will be the same as heretofore. But the present Vice-Presidencies will be discontinued, beginning with the 1930 administrative year. Under the new plan each Professional Activity recognized officially by the Council will be represented by a Vice-President, he being the Chairman of the respective activity.

The Council has amended the By-Laws of the Society to conform to and put into effect the new system, which will make the Society procedure more effective and closely knit. Each Professional Activity Vice-President will be nominated by committees elected by those showing their interest in the respective activities by participating therein. The total number of voting members of the Council from year to year will depend on the number of officially recognized Professional Activities. There will be each year on the Council, as heretofore, a President, Past-President, six councilors and a Treasurer; and, in addition, as Past-President, the Member who served as President during the second year prior to a given administration.

As contemplated by the recommendations of the Committee on Reorganization, the Council has canvassed the members by mail as to the need for and their willingness to support the various Professional Activities that have been under discussion currently.

Eight Activities Recognized

As a result of this, and study of the situation as a whole, the Council has, according to provisions of the plan, recognized eight Professional Activities. These are

Aircraft
Aircraft-Engine
Diesel-Engine
Motorcoach and Motor-Truck
Passenger-Car
Passenger-Car Body
Production
Transportation and Maintenance.

For some of these activities the Society has had representative committees for several years. In the case of these, the new committees named by the Council are virtually the same in personnel as the committees named at the first of the present administrative year. The prescribed method of recognition of an activity by the Council is by naming a committee to represent it. The Council has appointed a Committee for Aircraft Engines, in addition to the Committee representing Aircraft. The Diesel-Engine Committee and the Motorcoach and Motor-Truck Committees are new. The personnel of the Passenger-Car Committee is the same as that of the Motor-Vehicle Committee which was appointed early this year; the word "passenger-car" being used as being more descriptive of the scope of the work of the Committee. The Passenger-Car-Body Committee is new. The Production Committee is made up of members of the Society appointed to it last January. The same is true of the Transportation and Maintenance Committee, the name of the Committee being changed by adding the word "maintenance," to make it clearer that service matters are included in the program of the Committee so far as interest and the holding of meetings are concerned.

The members named by the Council to serve on the Professional Activities Committees for the remainder of this administrative year are:

AIRCRAFT COMMITTEE

E. S. Land, *Chairman*

E. E. Aldrin	G. C. Loening
D. M. Alexander	C. J. McCarthy
C. H. Colvin	W. P. McCracken, Jr.
H. M. Crane	A. L. Martinek
S. M. Fairchild	C. N. Monteith
L. D. Gardner	G. A. Rentschler, Jr.
W. E. Gillmore	L. D. Seymour
Carl Harper	Mac Short
J. C. Hunsaker	W. B. Stout
B. G. Leighton	Chance M. Vought
W. L. LePage	E. P. Warner
G. W. Lewis	J. E. Whitbeck

L. M. Woolson

AIRCRAFT-ENGINE COMMITTEE

L. M. Woolson, *Chairman*

E. E. Aldrin	W. P. McCracken, Jr.
E. T. Birdsall	George J. Mead
E. S. Land	Arthur Nutt
B. G. Leighton	C. F. Taylor
G. W. Lewis	E. P. Warner

A. V. D. Willgoos

DIESEL-ENGINE COMMITTEE

R. J. Broege, *Chairman*

A. C. Attendu	H. A. Huebotter
E. T. Birdsall	J. H. Hunt
W. T. Fishleigh	Elmer A. Sperry
N. H. Gilman	O. D. Treiber
W. H. Himes	L. M. Woolson

MOTORCOACH AND MOTOR-TRUCK COMMITTEE

A. J. Scaife, *Chairman*

B. B. Bachman	S. W. Mills
W. J. Baumgartner	L. H. Palmer
C. J. Bock	A. W. Scarratt
A. W. Herrington	E. M. Schultheis
M. C. Horine	G. H. Scragg
W. F. Klein	P. V. C. See
A. A. Lyman	E. M. Sternberg

F. A. Whitten

PASSENGER-CAR COMMITTEE

George L. McCain, *Chairman*

J. M. Crawford	W. C. Keys
W. J. Davidson	F. F. Kishline
W. N. Davis	F. Sergardi
W. T. Fishleigh	L. S. Sheldrick
W. R. Griswold	Alex Taub
H. L. Horning	P. L. Tenney
L. P. Kalb	F. E. Watts

A. M. Wolf

PASSENGER-CAR-BODY COMMITTEE

W. N. Davis, *Chairman*

G. C. Baker	John B. Judkins
H. A. Brunn	A. L. Knapp
O. H. Clark	G. C. Mercer
H. R. Crecelius	A. J. Neerken
A. de Sakhnoffsky	A. E. Northup
W. E. England	C. B. Parsons
L. C. Hill	L. L. Williams

H. R. Wittkowsky

PRODUCTION COMMITTEE

E. P. Blanchard, *Chairman*

J. B. Armitage	W. W. Nichols
G. W. Blackinton	Erik Oberg
P. A. Brown	L. L. Roberts
L. A. Churgay	V. P. Rumely
F. H. Colvin	E. N. Sawyer
A. R. Fors	F. W. Stein
G. W. Gilmer, Jr.	E. W. Weaver

John Younger

TRANSPORTATION AND MAINTENANCE COMMITTEE

F. C. Horner, *Chairman*

W. F. Banks	H. V. Middleworth
Donald Blanchard	E. S. Pardoe
W. M. Clark	G. O. Pooley
Henry Dakin	Eugene Power
H. L. Debbink	T. L. Preble
E. Favary	A. J. Scaife
F. K. Glynn	F. J. Scarr
E. H. Grey	Pierre Schon
F. W. Herlihy	P. V. C. See
C. C. Humber	S. B. Shaw
H. W. Kizer	F. W. Templin
A. F. Masury	J. F. Winchester
A. S. McArthur	E. C. Wood

The Aircraft and the Aircraft-Engine Committees held sessions in Cleveland last month during the week of the Aeronautic Meeting. The former named the following as members of its Nominating Committee: Dr. George W. Lewis, *Chairman;* C. J. McCarthy, C. B. Harper and L. D. Seymour. The Aircraft-Engine Committee named E. P. Warner, *Chairman;* J. Don Alexander, Dr. Karl Arnstein and W. L. LePage. The duty of these Nominating Committees is to designate one consenting nominee for the respective Vice-Presidency on or before Oct. 1 next.

The other six Professional Activities Committees will meet this month for the same corresponding purpose. In the inaugural year of any Professional Activity its Vice-President is nominated as indicated above. During each subsequent year each Vice-President of a Professional Activity is to be nominated by a Nominating Committee, consisting of four Society members, elected at a stated Business Session of the activity; the nominee to be named on or before Sept. 1.

Function of Professional Activity Committee

The function of a Professional Activity Committee is to represent and act for the members of the Society interested in the activity, conferring as necessary with the Council and the Administrative Committee, and with

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National Meetings

Production—Oct. 2 to 4
Hotel Statler, Cleveland.

Transportation—Nov. 12 to 15
The Royal York, Toronto.

Annual Dinner, Jan. 9, 1930
New York City.

Annual—Jan. 21 to 24, 1930
Book-Cadillac Hotel, Detroit

St. Louis Aeronautic—Feb., 1930

Detroit Aeronautic—April, 1930

Section Meetings

Metropolitan Section—Sept. 19
House-Warming Party, New Ballroom, A. W. A. Club, 357 West 57th St., New York City.

St. Louis Section—Sept.

Washington Section—Sept. 25
City Club, City of Washington.
Subject—Front-Wheel Drive.

Wichita Aeronautic—Sept., 1929

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the Standards and the Research Committees with regard to the work of the latter pertaining to the activity concerned.

Each Professional Activity Committee is to consist of not less than 12 voting members of the Society, including as Chairman the Vice-President representing the activity. The members of each Professional Activity Committee, including the Vice-Chairman, will, after the inaugural year of the activity, be appointed by its respective Vice-President, with the approval of the Council. The Chairmen of the corresponding professional groups of the geographical Sections of the Society will be automatically members of the Committee. Each Professional Activity will have a Meetings Committee, a Membership Committee and such other committees as its Chairman deems desirable and the Council approves.

Each Professional Activity is to hold at least one Business Session each year.

Result of Member Canvass

In the recent canvass of the sentiment of the members by the Council, 1579 returns were received. On the average, each of these members expressed interest in four of the activities listed in the canvass form. These expressions of interest, amounting to 6000, were as follows:

Aircraft Engine	731
Motorcoach and Motor-Truck	669
Passenger-Car	664
Diesel-Engine	656
Aircraft	631
Production	440
Transportation and Maintenance	402
Industrial Engine	402
Tractor	338

Passenger-Car-Body	266
Marine	245
Motorcycle	172

Other activities for which there were 10 or more expressions of interest were:

Fuel and Lubricants	51
Maintenance and Service	43
Marine Engines	40
Automotive Engines	39
Lubrication	26
Passenger-Car Engines	26
Research	26
Iron and Steel Metallurgy	13
Accessories and Parts	11
Lighting, Starting and Ignition	11
Transmissions	11
Tractor Engines	10

Present Work to be Maintained

Of course, the recognizing, under the reorganization plan, by the Council of the eight Professional Activities above named does not mean that the Society will not continue to maintain its work of general engineering, standardization and research, and work devoted to special lines of engineering and production interest. Other activities will be recognized officially by the Council, in its discretion, as adequate desire and promise of support are expressed. As stated above, official recognition of a Professional Activity means the naming of a committee to represent it, the Chairman of the activity being a Vice-President of the Society and a voting member of the Council. A relatively large number of Professional Activities has been so recognized, considering the newness of the plan. Further development will need and will have adequate study. The new method means self-government for those interested in one or more activities, expressed by participation in meetings and in committee work, as well as in availing of the pertinent published matter. It also means authority and centralization of procedure, as well as responsibility individually placed and accepted. It should, and without doubt will, mean improved and more satisfactory work, and faster progress along specialized and general lines.

There is no thought of dividing the Society members or their interests. Division would weaken, not strengthen; enervate and complicate and not knit closely commensurately with community of interest. The basic foundation of the alliedness of the various phases of automotive engineering is the astonishingly large number of points of contact inevitably resulting from community of interest, the things that must be studied and advanced jointly, and that cannot be advanced as well or at all separately. The necessary features of the Society's general activities will be not only as conspicuous and helpful as ever, but continue in increasing degree and effect.

Technicalities at Aeronautic Meeting

Engineering Subjects Hold Interest at Cleveland Despite the National Air Races and the Aircraft Exposition

UPWARD of 300 aeronautic men and others interested in aircraft development sat in at the sessions of the Cleveland Aeronautic Meeting of the Society during the first three days of the week of August 26, although National Air Week was replete with counter-attractions, such as the daily air races and other events at the Cleveland Airport, airplane exhibits at the Auditorium, daily meetings of the various sections of the Aeronautical Chamber of Commerce of America, and other events connected with aviation. Papers presented at the five technical sessions of the Society proved definitely interesting and very informative to those who are concerned primarily with the design and production of safer, faster and more economical airplanes and lighter-than-air craft.

At the Aeronautic Dinner on Tuesday night all available space in the ballroom of the Hotel Cleveland was occupied by 350 members of the Society and the Aeronautical Chamber of Commerce and their guests. The particular attractions at the dinner and the technical session which followed immediately were an address by the Hon. David S. Ingalls, Assistant Secretary of the Navy for Aeronautics, who is a Cleveland man; the presentation by Senor Juan de la Cierva of a paper on the Autogyro, of which he is the inventor; the presentation of the Society's Manly Memorial Medal for 1928 to S. D. Heron; an address by William B. Stout and papers given by Edward P. War-

ner and Russell L. Putman. Unannounced features of the evening were the presence as guests of honor of Mrs. Louise Thaden, winner of the Women's Derby flight from Los Angeles to Cleveland for the air races, and Miss Amelia Earhart, who won third place in the Derby, both of whom made very brief but most pleasing remarks.

About 75 attendants at the meeting made the trip in two motorcoaches on Tuesday afternoon to Akron to inspect

work in progress on the construction by the Goodyear-Zeppelin Corp. of the gigantic dock or hangar for the 6,500,-000-cu. ft. helium airships being built for the Navy. The hangar is a radical departure from any heretofore erected, as well as the largest in the world. Like the ships, it is at present in only the early stages of construction. A detailed description of both the ships and the hangar was given in a paper by Dr. Karl Arnstein published in the May, 1929, number of the S.A.E. JOURNAL, beginning on p. 465. It was through the courtesy of Dr. Arnstein that the inspection trip to the Goodyear plant was arranged.

Papers of Prime Importance

To particularize as of surpassing importance any one or several of the papers presented at the technical sessions would be presumptuous and might easily prove erroneous, for no one knows at this stage of aeronautic development what may prove to be the most important in the next few years. But undoubtedly aerodynamics of the airplane is of major importance, for it involves safety, performance and economy of operation. Ralph Upson's claim that it is possible to design a plane that will be so automatically stable that it will recover from any tendency to go into a spin even if the pilot moves the controls in the wrong direction makes his paper on A Coordinated System of Basic Design worthy of very careful study.
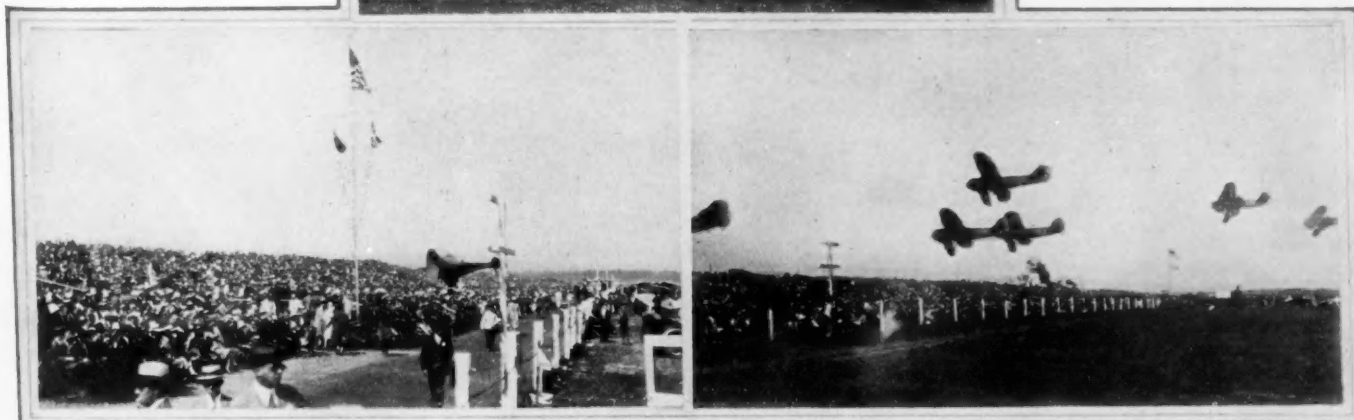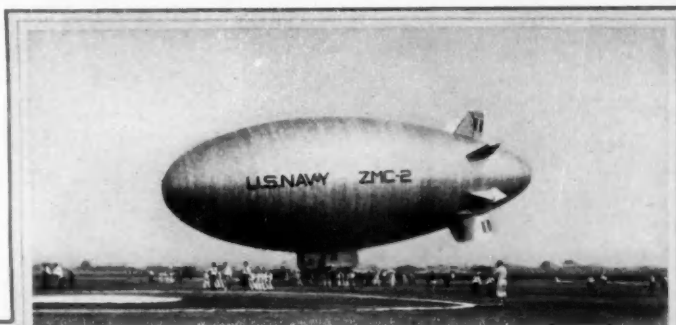
AT CLEVELAND MUNICIPAL AIRPORT DURING THE NATIONAL AIR RACES

The New Metal-Clad Experimental Airship Built for the Navy, on Its First Long Flight from Detroit. Some of the Spectators in the Grandstand. Competitors in One of the Airplane Races

The question of liquid-cooled versus air-cooled engines seems likely to be reopened as a result of investigations carried on by the Army and the Navy. The results of the research on this subject, as given by Gerhardt W. Frank in his paper on High-Temperature Liquid-Cooling merit the attention of all aircraft builders. Operators as well as builders will find the papers on propellers, which were given at the Propeller Session, of importance because of the greater efficiency and fuel economy realizable by the use of controllable-pitch propellers. The papers on the economics of air transportation which were given by E. P. Warner and William B. Stout at the Aeronautic Dinner Session should prove of value to operators and designers alike.

The quest for strong but ever-lighter materials of construction is never-ending. Contributions to avilable information on the subject of aluminum, magnesium and beryllium alloys, as given at the Light Alloys Session on Wednesday forenoon, were listened to with close attention.

Aircraft-Lighting Report

Of primary importance at the Standards Session, with which the meeting

CAPT. E. S. LAND

Chairman of the Aeronautic Committee and Toastmaster at the Aeronautic Dinner

opened on Monday, Aug. 26, was the presentation of the report of the Lighting Subdivision of the Aircraft Division of the Standards Committee. This

report is given in full in this issue of the S.A.E. JOURNAL on p. 304.

Metal-Clad Airship in Pictures

No paper on lighter-than-air craft was presented but motion pictures of the metal-clad ZMC-2, which made its first flights in August and flew to the Cleveland airport during the races, proved the success of this radical departure in airship development that may have much significance for the future.

The principle of the Autogyro has perhaps not been taken very seriously as yet by designers in this Country, but Señor de la Cierva's paper, printed in this number of THE JOURNAL, beginning on p. 204, presents the inventor's conviction that it is the coming type of airplane. Certainly all of the 350 attendants at the dinner followed the speaker's every word most attentively.

Those Who Made Meeting a Success

Success of the meeting was the result of the cooperative effort of many earnest workers in the Society and the industry. Credit belongs primarily to Capt. E. S. Land, Chairman of the Aeronautic Committee, who contributed a great deal of hard work before and at
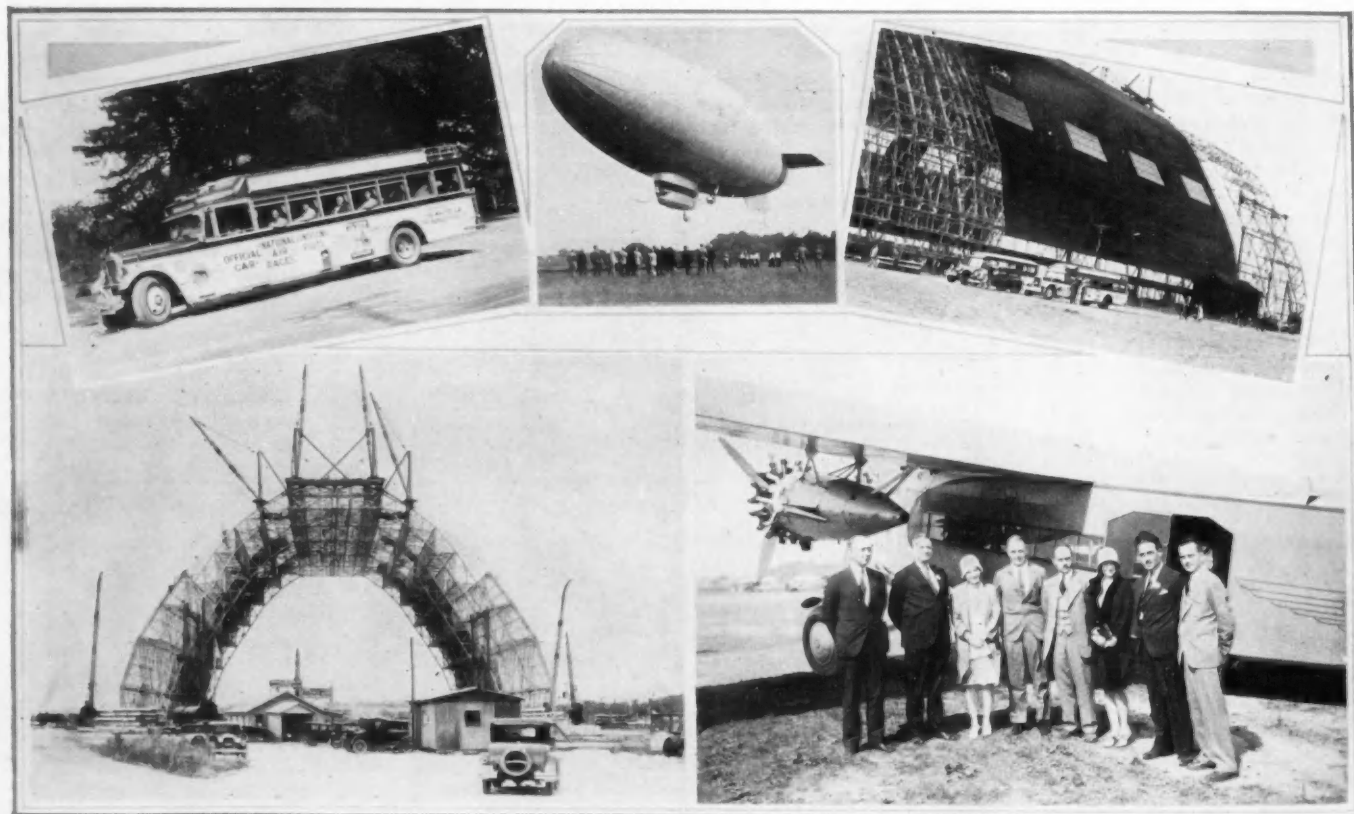
SEEN ON THE INSPECTION TRIP TO AKRON

(Upper Left) Motorcoach That Carried Some of the Meeting Attendants to the Goodyear Plant, Loaned by the White Co. (Upper Middle) Goodyear Defender Small Semi-Rigid Airship Taking Off. (Upper Right) Goodyear-Zeppelin Largest Airship Dock in the World, Under Construction for the New 6,500,000-Cu. Ft. Helium Airships To Be Built for the Navy. (Lower Left) End View of the Dock, Showing Truss Construction To Resist Wind Pressure. (Lower Right) S.A.E Representatives and the Golden Shell Which Carried Them from Cleveland to Akron. The Individuals (Left to Right) Are: Gerthal French, of the Sinclair Refining Co.; Col. T. A. Peck, Consulting Engineer for the Shell Petroleum Co.; Miss Judy McCormick, C. F. Clarkson, A. J. Underwood and Miss S. A. Kelly, of the S.A.E. Staff; A. J. Doyle, of the Sinclair Refining Co.; and C. B. Whittelsey, Jr., of the S.A.E. Staff

the meeting; and to the supporting members of the Committee. For the prompt conduct of the various sessions in accordance with the program the thanks of all should be given to the chairmen. To them falls the lot of thanking the contributors of papers but getting no thanks themselves. Those who presided over the technical sessions were: Edward P. Warner, Standards Section; Lieut. C. B. Harper and Major Leslie MacDill, Propeller Session; L. M. Woolson, Powerplant Session; C. H. Chatfield, Airplane-Design Session; Capt. E. S. Land, toastmaster at the Aeronautic Dinner and Technical Session; and Carl B. Fritsche, Light-Alloys Session. W. E. England, Chairman of the Cleveland Section, which was host at the Aeronautic Dinner, presided at the opening of the dinner. Charles L. Lawrance made the presentation of the Manly Memorial Medal on behalf of the Society to S. D. Heron for the paper presented at a meeting of the Society in 1928 which best met the conditions of the award.

Appreciation of the members of the Society is due to E. R. Jackson and his committee of Cleveland Members who served on the Reception Committee. Also to Mr. Fritsche for the interesting showing of the motion pictures of the ZMC-2 as the closing feature of the meeting; to Dr. Karl Arnstein for arranging the inspection trip to the Goodyear plant at Akron; and to the White Co. for volunteering the use of a motorcoach for transporting members to the Cleveland airport and the Goodyear plant at Akron.

Cierva Speaks at Dinner Session

Describes His Autogyro, Demonstrated at Air Races—Heron Awarded Manly Medal—Secretary Ingalls Speaks

TUESDAY night's Aeronautic Dinner, at which the Cleveland Section was host, was replete with interesting features. Nearly 350 members of the Society and the Aeronautical Chamber of Commerce and their guests filled to capacity the ball room of the Hotel Cleveland and gave enthusiastic applause to the speakers. Professional dancing and singing during the dinner preceded the program of addresses and technical papers.

W. E. England, Chairman of the Cleveland Section, initiated the ceremonies following retirement of the entertainers with a brief expression of the pleasure it gave the Section to sponsor the dinner and entertainment, which he said were typical of the regular monthly meetings of the Section, with the exception that more notables or celebrities were present than usual. He then introduced Capt. E. S. Land, who presided during the rest of the evening.

Guests of honor humorously introduced by Captain Land and requested to stand and be recognized were:

Mrs. Louise Thaden, "newly crowned Queen of the Air"

Major-Gen. W. E. Gillmore, "heir apparent to the Air Corps"

Rear Admiral William A. Moffett, "another monarch of Naval aviation"

Dr. Karl Arnstein, "emperor of the lighter-than-air"

Harold Pitcairn, "one of the youngest airmail pilots, who is devoting his best work to experimenting and research"

Clifford Henderson, "one of our own celebrities, P. T. Barnum returned to earth"

C. F. Clarkson, "a sort of wheelhorse in the Society"

Don M. Alexander, "a monarch of the skies who put Pike's Peak in the West"

Brigadier-Gen. Frank P. Lahm, "another original aviator, a baloonatic—lighter-than-air, heavier-than-air"

L. M. Woolson, "king of Diesel engines"

Luther Bell, "wheelhorse of the Aeronautical Chamber of Commerce"

Miss Amelia Earhart, "the salt of the earth; the salt of the sea"

Charles L. Lawrance, "Paul Revere's horse"

Hon. David S. Ingalls, "our Navy ace of aces, the Assistant Secretary of the Navy for Aeronautics."

The Ladies Get in a Word

When Mrs. Thaden was introduced, the audience rose, appaluded vigorously and called for a speech. In a very happy vein that delighted her hearers, the winner of the "All-Hen Derby" narrated a few of the amusing incidents of the Women's Airplane Derby from Los Angeles to Cleveland. Mrs. Miller, who is a charming English woman, said Mrs. Thaden, and is very religious, like Mrs. Kunz, of New York, who says she prayed fervently from the time she took off until the time she landed, had about 15 forced landings on the way from Santa Monica, and when she was within about 50 miles of Cleveland had her 16th. When she crawled out of her ship and sat under the wing, she said, "Well, God, I have taken it this far; you take it the rest of the way." Ruth Elder had quite a hard time, too, said Mrs. Thaden. She lost several maps coming up from Tulsa to Wichita and had to land to find out where she was. She landed in a pasture where there were a lot of cows and other animals, which, being inquisitive, meandered up to investigate. As Miss Elder sat in the cockpit of her brilliantly red airplane for a moment after landing safely, she happened to look out and see all the creatures, and she prayed, "Oh, God, make them all cows." That is the kind of nice sports they had on the Derby, said Mrs. Thaden in conclusion; "most of us are glad it is over, but I do not think any of us would take anything for the experiences we have had, both in flying and in getting acquainted with one another."

Neither would the audience let Miss Earhart get by without making some remarks. "We have been called various-

GENERAL VIEW OF PART OF THE AIRCRAFT EXPOSITION ON THE MAIN FLOOR OF THE AUDITORIUM
Many Other Exhibits Were Displayed in the Main Building Basement and the Annex

SPEAKERS AND HOST AT THE AERONAUTIC DINNER AND TECHNICAL SESSION

The Hon. David S. Ingalls (Upper Left), Assistant Secretary of the Navy for Aeronautics. Russell L. Putman (Upper Right) Spoke on Selling Airplanes to Business Men. W. E. England (Center) Welcomed the Assemblage on Behalf of the Cleveland Section, Which Was Host of the Evening. William B. Stout (Lower Left) Warned the Industry To Be Prepared for a Sudden Psychological Effect That Will Make the Whole Public Want To Fly. Edward P. Warner Analyzed the Economics of Speed and Weight in Air Transportation

ly the 'Sunburn Derbyists,' the 'Powder-Puff Flyers,' 'Flying Flappers,' 'Angels,' 'Lady Birds,' 'Sweethearts of the Air,' and so forth. I just wish the idea could be got across that women's attitude toward aviation isn't materially different from that of men. I think all the girls in the race, if you could talk with them, would make you realize that."

Lawrance Presents Manly Medal

As Chairman of the Board of Award for the Manly Memorial Medal, Charles L. Lawrance made the presentation speech and presented the medal for the year 1928. He said in part:

A little less than 30 years ago a young man down in Washington was developing an airplane engine he had designed himself and was trying to get it made. An airplane did not exist at that time, although one was being built and he was to build the engine for it. People who knew him regarded him as a dreamer and possibly a fool. Had anyone looked at his design, they would have stifled a laugh, because, unlike any other engine, the cylinders were set around in a circle. No machine-shops could make the parts for his engine; they were too light and thin. He had to show them how to do it. Finally,

after a struggle of a couple of years, he evolved an engine that developed 50 hp. over a period of 50 hr. and weighed only about 150 lb. Charles Matthews Manly was the man who built the first modern airplane engine.

It is only in recent years that we have come up to the level of Charles Matthews Manly. It is therefore fitting that the Society of Automotive Engineers should award a medal known as the Manly Memorial Medal, and I am happy to award it for the first time, to Samuel D. Heron, who is a particularly happy choice in view of the development work he did for air-cooled engines at McCook Field some years ago and is responsible for making the air-cooled cylinder as efficient as regards specific fuel consumption as a good water-cooled engine. He also evolved the idea of enclosing the valve gear, not only to protect the working parts, but also to prevent lubricating oil from coming out and getting all over the engine. I am happy, therefore, to award this medal and the diploma which goes with it to Mr. Heron. The award is made for a paper he presented at a recent meeting of the Society dealing with what he thinks may be the future development of the air-cooled aircraft engine. It is a masterly paper and shows a great deal of thought and a very original point of view.

Mr. Heron's paper, entitled, The In-

Line Air-Cooled Engine, was presented at the Aeronautic Meeting in Chicago in December, 1928, and was published in the April, 1929, issue of the S. A. E. JOURNAL, p. 376.

Advance Due to Morrow Board

Most of the credit for aviation's rapid advance in this Country since 1925 or 1926 was given by Assistant Secretary of the Navy Ingalls to the Morrow Board appointed by President Coolidge. This board of very able men laid down a five-year program of what should be done in aviation and aeronautics by the War Department, the Navy Department and the Department of Commerce and "since that time aviation in this Country has, I think," said Secretary Ingalls, "surpassed that in every other country, commercially, in the Army and in the Navy." Continuing, he said:

I want you to remember that those wise men of the Morrow Board, who have given us the idea that has brought about this extraordinary development, did not just give us an idea to act upon immediately; they set forth a five-year program of Army and Navy development. That is important, first, for our National offence and defence, and, second, because, although the commercial people have done a great deal for aviation, every material development in engines and planes can be attributed at least to a considerable part to the military services. The hazard and the enormous expense of the advanced development of aviation makes it almost necessary that this sort of work be done by military organizations. Perhaps after months of preparation, tooling-up, and following specifications, the manufacturers of our great commercial development could build the military planes we would need in time of war, and after months of training we might teach the commercial pilots to shoot, navigate in different positions, land on carriers, bomb, and so on, but for the immediate present commercial aviation really has not changed the necessity for military development.

Cierva Tells of the Autogyro

Called upon by Captain Land to introduce Señor Cierva, Harold Pitcairn remarked that many people have felt that some improvement on the principle of the airplane should be sought and that Mr. Cierva was one of these. The success he has achieved has been the result of many years of arduous work, of deep mathematical calculations and a great deal of research. "I am convinced," said Mr. Pitcairn, "that the Autogyro embodies the correct theory of flight, at least for commercial purposes. Mr. Cierva has come to this Country so that others may have the opportunity to hear from him personally what the Autogyro is and see the results of his work."

The aerodynamic principle of the Autogyro, which enables it to take off and land at very sharp angles, and the inventor's latest improvements whereby the take-off run can be reduced to only a few feet, are described by the

inventor in his paper printed in this number of THE JOURNAL, beginning on p. 204.

On behalf of the Society and its guests, Toastmaster Land expressed most grateful thanks to Don Juan, saying:

"I want to congratulate you, sir, on the excellence of your English," for which Señor de la Cierva had apologized at the beginning of his address. "The attention of this audience is ample evidence of the excellence of both the English and the paper, which has been intensely interesting."

Sales Obstacles To Be Overcome

Other speakers on the technical program of the evening were Russell L. Putman, whose topic was Selling Airplanes to Business Houses; William B. Stout, who talked on the subject of Load Rating of Commercial Airplanes; and Edward P. Warner, who delivered a paper on The Economic Relationship of Speed and Weight in Air Transportation.

The three phases of Mr. Putman's topic with which the author dealt were (a) the attitude of business toward flying and its knowledge of the airplane as a practical business tool, (b) the way in which manufacturers can capitalize on the needs of business to sell airplanes, and (c) the sales organization and activities required to sell airplanes. A marked difference was pointed out between the business man's attitude toward travel by air in general and his consideration of the airplane for his own use. While he confidently predicts great growth in aviation enterprises and invests his dollars in aviation stocks, he thinks of flying as something apart from himself, expecting someone else to pay the fares and ship the goods that will make airlines profitable. His is a vicarious participation in the growth of the industry. To change this attitude sufficiently to sell airplanes to business houses, the three outstanding resistances to be overcome, according to Mr. Putman, are (a) fear, (b) high cost of transportation by airplane, and (c) lack of understanding of the utility of the airplane. He said further:

If airplane manufacturers are to develop sales in large quantity they must overcome the fear of air travel, which is a big job of the entire industry in getting across to the public the safety and sanity of ordinary flying. It should be told in everyday language, in terms of getting from this place to that place with comfort and dispatch. The people must learn to feel that they can climb into their own airplanes or into a transport with the same assurance of safe arrival at destination as in the case of train, steamship or automobile. Perhaps the only answer to this is the banding together of all aircraft manufacturers to carry on such an educational campaign. Reduction of costs to a basis that is comparable with that of other means of travel may be hoped for in the years ahead. Today that is not feasible, but the real index of the value of the airplane is accomplishment through a more effective use of time; we must show the business man what the airplane can accomplish and that in the saving of time lie profits. Finally, it becomes necessary to help the business man discover the uses to which he can put the airplane in his business. There are a multitude of uses for the airplane which even the airplane manufacturer has not yet discovered. The manufacturer can study the uses to which present owners are putting their airplanes and carry the story to other business houses. Perhaps more effective would be the selection of concerns that seem to be the best prospective purchasers and the studying of their situation and operations to determine in what ways the airplane can fit into the business as a practical and profitable tool.

Mr. Putman then went on to outline the organization and activities required to overcome the resistances, and predicted that the manufacturers who

GUESTS OF HONOR AT THE AERONAUTIC DINNER

(Above, Left to Right) Rear Admiral W. A. Moffett, Mrs. Louise Thaden, Miss Amelia Earhart, Dr. Karl Arnstein. (Below) Charles L. Lawrance, Who Presented the Manly Medal; S. D. Heron, To Whom the Medal Was Awarded; J. Don Alexander; and Harold F. Pitcairn, Who Introduced Señor Juan de la Cierva

survive in the competition for business will be those who invest wisely in aggressive sales cultivation instead of waiting for a slow development.

Stout Foresees Great Changes

Instead of reading his prepared paper, Mr. Stout took his theme for an extemporaneous address from Señor Cierva's paper and Mr. Putman's address. He said in part:

I do not think we need to spend money today in trying to educate the public intensively on flying in present-day craft, because with what we all have ready for tomorrow that interest is going to come naturally, and we shall have the space and be able to carry the loads and to do with load ratings what we could not even discuss today with intelligence. Ideas like the Autogyro, slotted wings, thick wings, metal construction, wide landing-gears, wheel tail-skids, closed cabins and so on are adding to the public's belief in flying. The record of the airlines all over the Country are doing very much to educate the public. I think we can predict that within two or three years at most, through some psychological effect similar to that produced by Lindbergh's flight, the entire public of the United States will decide it is time to fly, and then the industry will come. When that day comes, it is going to be up to this organization to have the type of equipment ready that can take care of the rush.

If there is one thing that we are altogether decided upon, it is that the present airplane is not going to be the future airplane. We are building today merely a forerunner of what we can see in the future. Every new development revises our analyses, changes our performances, our methods of production, our costs and maintenance figures. Two years ago in commercial work we built airplanes that had their inception from the old types of airplanes used during the war, and were satisfied with the performance of certain loads per horsepower. The foreign countries started in for extreme economy and we were all obsessed with the notion that our problem was to carry the greatest number of pounds with the least horsepower. But suddenly we put in 400-hp. engines and the price and operating cost go up enormously, theoretically at least, and we wonder where we can sell the airplanes. Then we find suddenly that everyone wants the high-powered airplane, and the low-powered plane is already obsolete. We have been building airplanes at a price of $50,000 to $55,000 at a rate of four a week and have not been able to keep up with the demand, without any sales force out.

The problem we have in the airplane business today is not an engineering problem; it is a human, psychological problem. It is deeper than just a sales problem. Engineering must solve it, but we must understand first that it is a problem of giving the public what it is going to have before it will take to the air, and safety is the first fundamental. Safety in our present planes is largely dependent on power, but we must go further before we can satisfy the public that we are building something it wants to ride in. If it looks like a grasshopper with a broken back, the people will not ride in it. The appearance must be there. Now that we are beginning to make trips of 10 hr. and more, they are going to demand more luxury. I believe they are going to demand more in the air than they ever demanded on the railroad. That is going to put a load require-

ment on the engines in the matter of larger fuselages in proportion to wing area. So figuring a load rating that will fit this problem, along with the engineering problems and safety and power problems, takes in so many factors that you are almost as badly off when you finish as when you begin.

Economic Speed-Weight Relationship

Edward P. Warner, in the concluding paper of the session, gave an analysis of the economic relationship of speed and weight in air transportation, which he illustrated with lantern-slide charts. Owing to the length and character of the paper, no attempt will be made to summarize it here. An indication of its nature is given by the author's summary, as follows:

In no ordinary case does seeking to operate at cruising speeds of more than 1.8 times the minimum flight-speed appear economically advisable at present. To increase cruising speeds beyond present levels, we must therefore increase landing speeds, and the possibility of taking that desirable step depends upon the use of engines, engine combinations, and the maintenance methods that will provide a virtually absolute safeguard against emergency forced landings and upon

the provision of airports large enough and smooth enough to permit of landing and taking off at very high speeds without undue difficulty or danger. These are the keys to the problem.

Commenting on Mr. Warner's paper, Captain Land said that his only objection to it was that it was altogether too convincing, as were his charts and figures. As he is working for an institution that is struggling for low landing-speeds, Captain Land does not want high landing-speed. In adjourning the meeting, he said he trusted that this was his swan song as any sort of an official of the Society, and expressed his thanks to those who had given him a great deal of cordial and heavy support throughout the last year. The work had been instructive to him, he said, and he thinks the Society is doing some splendid work. The new Constitution brings into the Society another set-up, in that the Aeronautic Committee has been divided into an Airplane Division and an Aircraft Engine Division, which he thinks is a wise move, as aviation is sure to become more important in the Society.

Airplane Design and Load Factors

Upson Presents Design System That Makes Plane Spin-Proof —Department of Commerce Requirements Discussed

A BASIC system of airplane design whereby the aerodynamic characteristics of the wings, tail surfaces, fuselage, struts and other appurtenances are coordinated to produce a desired result was presented at the Airplane-Design Session on Tuesday morning by Ralph H. Upson, of the Aeromarine Klemm Corp. Owing to the analytical and mathematical nature of the paper, it calls for careful reading and study in its entirety. And that it should receive such study by airplane designers is attested, first, by the remarkable success of the new metal-clad ZMC-2 airship designed by Mr. Upson and regarding which Captain Kepner, chief airship pilot of the Navy who flew the ship in its first five flights, including that from Detroit to Cleveland and return, said he had not found any detail that needed alteration, that it handled easily, is satisfactorily stable, that the fuel consumption is satisfactory and that the designer's figure of 70-m.p.h. speed is very reasonable.

The second major reason for placing great importance on the paper is the claim made by Mr. Upson that it is possible, by applying the design method outlined, to design an airplane that not only has no tendency to go into a spin but is so automatically stable that it will recover from a spinning tendency into which it may be put even if

an inexperienced or confused pilot moves the controls in the wrong direction. Such a plane already has been designed and tested, according to Mr. Upson.

The purpose of the paper is to present a basis for the practical coordination of existing data as a foundation for judgment in design and research, and it is believed to furnish a much improved method for establishing the best general proportions of wing. The author starts by taking as the basic requirement such fundamental characteristics as can be largely separated from the problem of wing design or assumed as attributes of the complete airplane, then discusses the independent variables consisting of the geometrical characteristics that can be varied to obtain maximum performance. He developed a weight and a drag equation each of which includes in the simplest possible form the combined effect of the various independent variables. The reduction to practice of the drag equation is discussed and interesting points bearing directly on practical design are presented. The author states that he believes that, in future, airfoil sections as well as general wing proportions will be chosen mainly by formula although experimental data are still insufficient for selecting the proper shape for a given thickness and range of lift,

as most of the many tests of airfoils are lacking in useful coordination.

General Conclusions from Design Method

The paper concludes with a number of interesting points bearing directly on practical design and that seem to have general application. Among these are that the best wing taper makes the root chord about five times the tip chord; elliptical plan-forms, taper in thickness ratio or camber, and other fancy wing forms possess no great advantage that cannot be closely approximated by a plain straight taper of proper proportions; internally braced wings of ideal proportions have from 20 to 30 per cent less drag and slightly less weight than the best arrangement of rectangular wing except when bracing rectangular wings with wire alone is possible; an arrangement in which the main diagonal struts of a conventional externally braced monoplane are supported by at least one intermediate stiffener is superior to a rectangular cantilever wing; adequate span is the prime essential for any design having a large powerloading; if the span is maintained, the area can be varied to a considerable range without seriously affecting anything but stalling speed; a cantilever wing with structural skin for a light airplane can often be made surprisingly thin provided any particularly harmful rate of vibration is not set up; induced interference in a low-wing monoplane apparently can be practically eliminated for power flight; an ideally streamlined fuselage can cause trouble if poorly placed in relation to the wings; and enforced contraction of air-flow is especially to be avoided; any gap between a fuselage or nacelle and the wings may be regarded with suspicion, particularly when the National Advisory Committee for Aeronautics cowling is used; the use of high-lift wing sections of fixed form depends on having an operating range at relatively high lift-coefficient, which is impossible in most cases where landing speed is the controlling factor; for the wings alone, if properly proportioned structurally, a lift-drag ratio of 25 is about the maximum except in very special cases.

The Bases of Design Approval

Discussion of Mr. Upson's paper was postponed by Chairman C. H. Chatfield until after the presentation of Prof. A. N. Niles's paper on Criteria for the Structural Strength of Airplanes. Owing to the inability of the author to be present at the meeting, his paper was summarized by Edward T. Warner. The paper by Professor Niles, who is professor of aeronautic engineering at the Guggenheim Laboratory of Stanford University, deals with the design loads specified by the Department of Commerce and with the alternative use of stress analysis and static-test reports to determine the adequacy of a given type of airplane to carry its design load. The paper constitutes an answer to various criticisms of the requirements of the Department of Commerce.

Professor Niles holds that in general the design loads as specified are satisfactory although numerous changes in their details should be made. Some of these changes could be made on the basis of existing information but most of them will require previous collection of additional experimental data. The general question raised by many airplane designers as to whether the criteria used by the Department of Commerce to determine the adequacy of the structural strength in submitted designs are necessary and sufficient, is divided by the author into the four following questions, which are discussed briefly

PARTICIPANTS AT AIRPLANE-DESIGN SESSION

Ralph H. Upson (Above) Expounded a Coordinated System for Designing Wings. C. H. Chatfield (Left), Chairman of the Session

in the paper with the hope that the author's views may lead to profitable discussion:

(1) Should the specified design load-factor be changed?

(2) Should the rules for the distribution of external loads be modified?

(3) Could not the number of loading conditions to be investigated by the designer be reduced?

(4) Should the policy regarding the calling for static-test data be revised?

Difficulty of Changing Load Factors

Regarding suggestions for changes in the specified load factor, Professor Niles states that the great advantage of the specification of breaking loads is that a static test gives definite answer as to whether the structure conforms to the specifications without the apparent test results being modified by several questionable conversion factors; and the difficulty of changing the load factors as specified so as to provide a different factor of safety from those implied by the present figures is that an important class of load to which an airplane is subjected is those encountered in flying through bumpy air, which may for the larger types of airplane be as great as or greater than those encountered in voluntary maneuvers. Commercial airliners and heavy mail-planes are subjected to about the same types of maneuver as Army transports and bombers.

Department rules give adequate factors of safety for designs of light planes used for sightseeing, photographic work and aerial taxiing. The same designs of plane are often used for military training purposes, for which the design loading is inadequate. For example, the question is whether some criteria can be devised for light heavily powered designs to separate those which will never be violently maneuvered from those which will be stunted and for which a higher schedule of loads should be promulgated. The load factors called for by the Department of Commerce, asserts the author, are sufficiently high but not too high for heavy lightly powered designs, but those for the lighter and more heavily powered designs should be raised so that severe maneuvers to which these types are subjected will not cause excessive stresses.

No question really exists, believes

Professor Niles, that some of the rules for the distribution of external loads should be modified, but a basic question is whether the agreement between pressure-distribution tests carried out in the wind-tunnel on a small-scale model and those made in flight is sufficiently close to permit the former to be used in place of the latter. Another question is whether the distributions found in tests of monoplane airfoil-models can be assumed to apply equally well to biplane cellules. Though tests made to date have demonstrated that the rules for load distribution can be modified in many details, they have not progressed sufficiently for many specific changes to be recommended, one reason being that no structural expert is attached to the National Advisory Committee for Aeronautics who could take the data as they are being obtained and study them from the point of view of the structural designer. The addition of such a man to the force at Langley Field has been recommended and Professor Niles agrees this step should be taken as quickly as possible.

Stress Analysis versus Static Tests

As to the relative merits of stress analysis and static tests as a basis of approval of applications for certificates, the author believes that the approval of designs should be based on a combination of the two. It would not be desirable to require extensive static tests of all the parts under loadings simulating those experienced in flight and landing that are likely to be critical, because of the expense involved and the difficulty of making some of them. The better system is to substitute the check of stress analyses for static tests whenever the former are sufficiently reliable and easier to make than the tests. On the other hand, static tests are relatively easy to make on some parts and types of construction, while reliable stress analyses are very difficult. There are types of construction for which so many static tests have been made and compared with stress analyses with satisfactory results that the engineer can safely approve new designs of these structures on the basis of such analyses alone.

Professor Niles does not regard it a hardship on the constructor to ask for either a static test or a stress analysis of every main structural part of the airplane, as a designer should have such data for his own information before offering his design to the public. Too great a tendency exists to design either by guesswork or copying, in which calipers take the place of the slide rule without checking results by any adequate method. If the static test is on the design in question and for the loading under consideration, a test is sufficient; if it is made on the same design but for a different loading or on a different design, the test analysis is

S.A.E. Booth at the Show
Displaying Applications of Standards to Aircraft Equipment

nothing more than a statement of how the test indicates that the design under test is satisfactory. The stress analysis is of great importance to the designer as a saver of either expense or structural weight. By utilizing the results of past tests and making the adjustments necessary to allow for the differences between the structure tested and that being designed, the most efficient design is much more likely to be found and at much less cost; in other words, a stress analysis properly carried out means that past experience is utilized to save expense and weight. However, before a design goes into quantity production, one example should be given a strict static test, but for the experimental and development work and for designs of which only a few articles may be constructed, complete tests are not needed unless construction is unusual. In conclusion, Professor Niles believes the manufacturers soon will be forced by competition to make such tests, but that they will also find it necessary to make complete stress analyses to obtain the most economical use of materials.

Danger in Applying Mathematical Methods

Referring in the discussion to Mr. Upson's paper, Mr. Warner said that he thinks it is a particular paper and that the method described is of enormous value and ought to be more generally applied. Mr. Upson is the first person who has really taken the trouble and had the necessary knowledge and ability to sit down and work it out for not merely the wing section but the wing as a whole and for the performance of the airplane, both as to aerodynamic and structural quality. He hopes that the method will be extended to calculating performance of the airplane, which will be a further step forward. Mr. Warner pointed out the ne-

cessity of being very careful, in applying the mathematical methods, not to overrun the bounds of their practical application, a danger to which Mr. Upson has also called attention. Almost all of these purely mathematical aerodynamic analyses carry the lift coefficients on indefinitely and take no account of maximum lift-coefficient. The works of a number of Continental writers who have treated the general theory of airplane performance and equilibrium have often suffered seriously in value because assumptions were made that were unduly general, forgetting that the assumptions had limited applications. Mr. Warner also questioned if it is not necessary to give a warning regarding the lower end of the curve of effective wing-taper and said he would be interested in Mr. Upson's tapering the wing down to a point that would be about a 4-to-1 ratio without getting the ribs and wing spars substantially heavier than the pure theory as developed would indicate.

Regarding the practical limitation of wing taper, Mr. Upson responded that he had tried to take the most conservative weight variation conceivable with respect to taper variation for the reason that the results did not seem to be coming out remarkably favorably to the large-degree taper and he did not want to emphasize this more than was necessary.

In the weight formula given in the paper he assumed the spar flanges, for example, to be proportional in weight per foot to the root weight per foot for all degrees of taper which ignores the more favorable curve of stress in the case of the spar for a tapered wing. Similarly, he took the rib weight by total load and area rather than by calculating the extreme theoretical advantage that might be derived from the very light stresses at the end of a highly tapered wing.

Concerning the applicability of theory in general, Mr. Upson said that no theory is ever complete and an incompetent engineer using the theory elucidated in his paper, or any other theory, is still an incompetent engineer.

Comments on Niles Paper

Two suggestions regarding the load factors used in airplane design were made by Richard M. Mock, aeronautic engineer, of New Castle, Del. One of these is the side-load landing condition. We are now neglecting, said Mr. Mock, the tread of the landing-gear and the relative distance from the center of gravity to the ground. Treads are now becoming 18 ft. or more and imposing a greater load on the lower portion of the structure, but the present requirements completely neglect the function of the tread. In a low-wing airplane or an amphibian, the center of gravity is very low and the landing-gear side-loads are much lower than in an air-

plane in which the center of gravity is high.

The other factor which Mr. Mock had in mind is that the tail surfaces are being designed according to the load imposed by the Department of Commerce requirements, which are in inverse ratio to the gross weight and neglect completely the fact that the loads imposed on the tail surfaces are functions of maneuverability of the airplane and are therefore similar to the loads imposed on the wing. He has known of instances of airplanes powered with a 200-hp. engine and having certain gross weight, in which 300-hp. engines were substituted without increasing the gross weight of the airplane; but the technical and literal interpretation of the Department's requirements as to loading on the tail indicates loadings exactly the same, regardless of the power and maneuverability. The greater engine power, without changing the gross weight of the airplane, made the plane more maneuverable and imposed greater loads on the tail surfaces. Manufacturers are therefore of their own accord imposing greater design loads when the power is increased.

Must Depend on Pilot's Discretion

Mr. Warner, referring to suggested changes of the load factors, said that considerable parts of the Aeronautic Safety Code, upon which the Department of Commerce rules were based when they were first drafted four years ago, were used to divide all airplanes into two classes: those which were going to be flown acrobatically without a limit, and those which were to be used under conditions that made it virtually possible to guarantee they would not be flown lawlessly. We have progressed far enough now so that we have a clear knowledge of where the load on the airplane is coming from and must recognize that some limitation must be placed on acrobatic flying. Any airplane that has reasonable maneuverability can have a load factor in excess of 10 if the pilot pulls up hard enough from very high speed, but no airplane is going to be designed to stand that. It must be assumed that the pilot will show a considerable degree of discretion. Mr. Warner suggested that a sign or notice be posted on the instrument board warning that the assumed maximum speed of the plane, for example, is 130 m.p.h. and that it is never to be dived in excess of 140 m.p.h. If this were done, the airplane could be designed to stand an abrupt pull-out from that speed with a factor of safety of a fraction over a unit. The pilot cannot be protected against himself beyond a certain point, as it is impossible to build a small high-powered airplane that cannot be wrecked by a pilot who sets out to do so.

Landing factors are somewhat mis-leading, asserted Mr. Warner, as there is no limit to the loads that can be imposed on a landing-gear, but it is necessary to impose an arbitrary specification and this depends on the service to which the machine will be put. He said he did not pride himself much as a pilot but was sure he could put a much higher landing-load factor than 2.3 or 1.9 on a machine.

Mr. Warner was highly in accord with the suggestion that "a structural engineer should sit on top of these research data all the time, receiving them in his arms as they come off the airplane and working in close liaison with the test people, so that when the test is made, if it should suggest a change, that the change would be made before the job was completed and the airplane sent off elsewhere." As a matter of fact, when the researches were taken up in 1919, Langley Field did start to do structural work and several reports were issued on torsion of fuselages, torsion of wings, and thrusts. Unfortunately, this was stopped about eight years ago.

Load factors in bumpy air should be studied intensively, Mr. Warner said. It is difficult to secure conditions for making such studies, and such tests as have been made have given negative results. When Lieutenant Doolittle flew over the mountains from Boston to Dayton, Ohio, looking for bumps with an accelerometer on his airplane, he encountered several rather severe bumps but never got a load factor in excess of 2.5 and concluded that the magnitude of the stresses in rough air is overestimated by the pilot and the designer. Nevertheless, Mr. Warner thinks that it would be difficult to design a rigid ship that could withstand the worst air conditions that have ever been known to exist. He referred to records of hail storms in which vertical velocities of 60 m.p.h. were observed. If it is not to be assumed that the pilot will be able to avoid these worse storms, it will be necessary to run the stresses far beyond present limits on the heavier airplanes as well as on the lighter ones if they are to withstand the most severe maneuvering with which any pilot would be tempted to experiment.

Powerplant Session

Masterly Papers on High-Temperature Liquid-Cooling and the Gaging of Engine Performance

THE Powerplant Session held on Monday evening was one of the most interesting and informative sessions ever held at a meeting of the Society. It was the occasion of intensive discussion of intensive research and study. L. M. Woolson presided.

J. H. Geisse, vice-president of the Comet Engine Corp., who has had a long and varied experience in the aeronautical engine field, presented a paper on the subject, Gaging Engine Performance. Its purpose was to set forth in an analytical way the factors to be considered in gaging engine performance, the author feeling that these factors had been much ignored. He argued that all factors exclusive of reliability can be evaluated with sufficient accuracy to provide a good basis for choice of engines, the factors to be considered being durability; weight per horsepower of the complete powerplant, including radiator and cowling; head resistance; fuel consumption; and first cost. Generally speaking, the wear on parts does not affect reliability when the rate of wear is known and parts are replaced accordingly. Plane performance is not determined by powerplant weight per horsepower but by total weight per horsepower. An increase in powerplant weight can be compensated for by a decrease in pay-load and fuel load and duplicate airplane performance obtained.

One of Mr. Geisse's conclusions was that increasing the weight of a 200-hp. engine from 400 to 494 lb. would be justified if the time between top overhauls could be increased from 150 to 183 hr., that between major overhauls from 300 to 366 hr., and the total life from 3000 to 3650 hr. He said also that for every 1-per cent increase in durability gained by the use of low mean effective pressures a saving of $144 can be had, in addition to an initial saving of $555, this involving an increase in airplane and engine weight of 172 lb., an increase in power required of 3 per cent, and a considerable reduction in the ratio of pay-load to total load.

Who Should Develop the Cowling?

Mr. Geisse said that the engine manufacturer should develop the engine cowling and that his doing so would bring a saving to the industry as a whole, the engine maker having only one cowling to develop for each engine type. At the present time the airplane maker, in choosing a new engine, has to mount it, develop a cowling, and determine a propeller setting before he can determine whether the new engine will give better or poorer performance than the old. Mr. Geisse's purpose in presenting the paper was to provoke helpful discussion.

Dr. S. A. Moss said that mean effec-

Chronicle and Comment

The Cleveland Aeronautic Meeting

ALTHOUGH registrations at the Aeronautic Meeting in Cleveland last month aggregated 267 at the technical sessions, not including the 350 attendants at the Aeronautic Dinner and the technical session following it on the night of Aug. 27, the meeting was notable more for the importance of the papers than for the attendance. All the papers were excellent in quality and dealt with topics of utmost immediate and future importance to the industry. Much of the information was presented for the first time.

Publication of these and other papers presented at the meeting, together with discussion of them, will be hastened as much as possible consistent with the balance required in the S.A.E. JOURNAL to give proportionate attention to other automotive activities of the Society. Nearly all of the papers were preprinted in advance of the meeting and a limited number of copies of many of them are available to those who write promptly for them to the headquarters of the Society.

A Noteworthy Meeting

A MOMENTOUS meeting was held in Detroit on Aug. 31, when a group of leaders in the motorboat engineering field took part in an open and inspiring discussion of the present problems of design and construction in that industry. The motorboat industry not only became articulate but effectively plain-spoken in revealing its technical difficulties. As C. F. Kettering, Chairman of the meeting, remarked, the recognition and definition of the problems are the first steps toward their solution and toward the standardization of boats. A report of the meeting appears on p. 311 of this issue of THE JOURNAL.

Riding Comfort Defined

RIDING-quality has been one of the most baffling problems confronting the automotive research engineer. It has defied definition and formula. Riding comfort has naturally been assumed to depend upon the nature of the vibrations of the motor-vehicle, their amplitude, frequency and direction. Engineers therefore first turned their attention toward the development of instruments which would enable them to measure and record these various characteristics of car vibrations. However, thus far no satisfactory or convincing correlation has been made between car-seat movements and subjective reactions of passengers, and the need of a definite measure of riding fatigue has become increasingly urgent.

Such a standard of measurement can be set up only after a thorough investigation of the nature of fatigue incident to motor travel. This task has been undertaken by Dr. Fred A. Moss, head of the department of psychology of George Washington University and a medical doctor of high standing, who has won international recognition by his studies of industrial fatigue.

The work is under the direction of the Society's Research Subcommittee on Riding-Qualities with funds provided by representative companies in the industry. Gratifying progress has been made during the first few months, as recorded in Dr. Moss's progress report, which appears on p. 298 of this issue.

Your $840,000,000-a-Year Saving

SEVERAL years ago the Society obtained estimates from about 80 prominent automotive engineers as to the difference that would exist in the aggregate cost of automotive products if there were no S.A.E. Standards. The average of the estimates received was 30 per cent, and, to be conservative, this figure was halved. The valuation of motor vehicles and parts produced in the United States and Canada in 1928 was estimated by the National Automobile Chamber of Commerce at a little more than $4,740,000,000. If S.A.E. Standards had not been available, this amount would have been 15 per cent greater, or approximately $5,580,000,000, figured on the foregoing basis. That is, the industry would have had to expend about $840,000,000 more than it did to produce last year's output. Has S.A.E. Standardization paid? Refer to the article on p. 305 of this issue of the S.A.E. JOURNAL.

Roster Revision Blanks Mailed

BLANKS for recording changes of position and address, for use in revising the S.A.E. Membership Roster, were mailed to all members the first week in September. If members who have made changes in their professional connection, in their position in such connection, or in their business or mail address as given in the 1929 Roster, will enter the correct present details on the blanks received and return them at once to the office of the Society, the work of revising the Roster will be considerably expedited. This will result in a somewhat earlier issuance of the new Roster after Jan. 1, 1930.

Members making any changes between Sept. 1 and Jan. 1, or after returning the revision blank, are urged to notify the Society promptly to assure inclusion of their correct connection, title and address in the 1930 Roster.

Heywood on Leave of Absence

CHARLES E. HEYWOOD, who has given his best to this Society for many years, is on an indefinite leave of absence as a member of the staff. Mr. Heywood's first work was in the Publication Department. He rendered long, effective service in the Standards work, and latterly has been manager of the Meetings and Sections Department. He has also taken a leading part in publication matters and in the studies involved in the recently adopted reorganization plans in connection with official recognition of Professional Activities of the Society.

S. A. E. PRODUCTION MEETING

Hotel Cleveland

Cleveland, Ohio   **Oct. 2 to 4**

In Cooperation with

National Machine Tool Congress
Sept. 30 to Oct. 4

American Society of Mechanical Engineers
Sept. 30, Oct. 1

Wednesday Evening, Oct. 2

Economical Production Quantities . . . . F. E. Raymond, Professor, Massachusetts
Institute of Technology

The subject of Professor Raymond's Paper will be the exhaustive study he has been making of economic
production quantities. This study included an extended trip to a considerable number of promi-
nent automobile plants and the paper will deal with the subject in a thoroughly up-to-date way

Thursday Evening, Oct. 3

This Session will be a forum for discussion of
(1) Application of Standard Machine-Tools to Automobile Manufacture
(2) Results in Production Due to New Features of Machine-Tool Construction
(3) Synchronizing Automobile Parts at Assembling Lines
(4) Basis of Replacing Machine Equipment

Friday Evening, Oct. 4

Production Dinner (Informal)

TRANSPORTATION MEETING

Hotel Royal York

Toronto, Canada   **Nov. 12 to 15**

Tuesday, Nov. 12

Morning—Motorcoach Session   Afternoon—Motorcoach and Motor-Truck
Body Session

Wednesday, Nov. 13

Morning and afternoon sessions will be held jointly with the Motor Transport
Division of the American Railway Association to present and discuss papers on
topics of importance to motor-vehicle engineers and the operators of motor-
vehicle fleets

Thursday, Nov. 14

Morning—Engine Session   Afternoon—Brake Session
Evening—Transportation Dinner

Friday, Nov. 15

Morning—Maintenance Session   Afternoon—Visits to plants of Toronto
Transportation Commission

The Autogiro

By Juan de la Cierva[1]

E SSENTIALLY the Autogiro consists of a fuselage that is propelled more or less horizontally through the air by an ordinary engine and propeller combination and wings that possess at least one degree of freedom with respect to the fuselage and turn around a central axis of rotation that is approximately perpendicular to the longitudinal axis of the fuselage, being articulated to a central hub and free to flap within rather wide limits. The present machines also have two small low monoplane fixed wings, that act mainly as supports for the ailerons, a fixed tail, elevator, fin and rudder.

Among the advantages claimed for the Autogiro are perfect stability, great flexibility, great adaptability, safety and the possibility of landing and taking off in a restricted area. The author claims that it is superior to the airplane for almost every purpose and is particularly adapted to civil aviation uses such as passenger transport, night mail service and especially for private flight.

B ETWEEN 1912 and 1919, I was an airplane enthusiast and constructed several. In 1919, my last airplane, a big three-engine biplane, crashed after stalling near the ground and then I realized that the airplane had fundamental limitations. I began to revise my views on aviation and conceived the idea of studying the heavier-than-air flight from a general point of view and of analyzing every particular type of flying machine to see if I could find some method of flying other than the conventional airplane, ornithopter and helicopter and free from the fundamental faults of these.

Fortunately I discovered a new general formula for heavier-than-air craft, which, expressed in generalities, consists of a framework or fuselage, propelled more or less horizontally through the air by an ordinary engine and propeller combination, but in which the wings, though not connected to any engine, are given at least one degree of freedom in relation to the fuselage. Those wings will move along the relative path constructionally fixed, under the component parallel to that path of the reaction of the wind on them, unless this reaction is perpendicular to the path, which would be a very particular case. This gives an answer to the question so many times asked "Why should the Autogiro wings move?" To answer "Why should they not move?" would be far more difficult. The essential feature of the new type of flying machine is that the speed of displacement of the wings through the air is no longer immutably that of the frame or fuselage and all kind of possibilities are thus opened. Such a machine can fly at a very slow speed while its wings are moving very fast, eliminating the very reason of stalling; it can descend vertically while the wings are traveling at high speed in an oblique trajectory; it can be brought to a momentary standstill condition without the wings stopping their motion because of the inertia and are still giving a certain amount of lift; and, finally, it can land at practically no speed while its wings are traveling at hundreds of miles per hour.

The Autogiro in the form that has been developed is a particular case of this theory and the only practicable one, in my opinion. The relative free motion of the

wings is a circular one around an axis of rotation approximately perpendicular to the longitudinal axis of the fuselage. The rotor wings or blades are universally articulated to a central hub and are free to move up and down or flap between very wide limits. They are also free to alter their relative angular-position with restriction imposed by an elastic interbracing. In addition to the rotary system, the present Autogiros have two small low monoplane fixed wings, which act mainly as supports for the ailerons. A fixed tail, elevator, fin and rudder complete the controls, as in the case of an airplane. The engine drives a tractor propeller and the whole machine is supported by a very wide, long travel undercarriage.

When the machine is in flight, the rotary blades are subjected to aerodynamic reactions and inertia forces. The blades will then adopt in every moment a positiion around the hinges such that the resultant of all those forces passes through the center of articulation. The main component of the wind reaction, which is the lift, will be balanced by the component of the centrifugal force and the blades will adopt a conical attitude. The dissimetry of the speed in opposite blades, when the machine has a horizontal motion, will produce a considerable lateral displacement of the center of pressure, but no tilting movement can be transmitted to the fuselage, because of the articulations, and the result of this dissimetry will only be a flapping motion of the blades, which rise when going forward and descend coming backward. The idea of the articulations only came to me in 1922. Before that date, I tried other solutions for the dissimetry, but unsuccessfully. The gyroscopic action, entirely suppressed by the articulations, made also impracticable the Autogiro with a single rigid rotor and it was only on Jan. 31, 1923, that the first articulated Autogiro flew at Madrid, covering a closed circuit of 4 km. (2.458 miles) at 25 m. (82.021 ft.) off the ground.

As I said before, in the Autogiro, the lift is partially independent of the speed of displacement. When the machine is stopped in the air, the blades continue their rotation at first through their inertia and when the machine starts to descend under the action of gravity, they act as a very efficient parachute, breaking the

[1] Cierva Autogyro Co., Ltd., London, England.

descent which is gentle and perfectly controllable, since the ailerons and elevator are functioning in the down wash of the rotor and never reach stalling conditions. The center of gravity is purposely placed slightly in front of the axis of the rotor so as to give the machine a tendency to glide forward. Nevertheless, a vertical drop of several hundred feet is made when pulling the stick back before the machine adopts a gliding attitude and, by keeping the engine turning slowly, continuous vertical descent can be obtained.

The First Actual Trials

In England, in the year 1925, a landing in still air was cinematographically recorded by the Government officials, in which the machine struck the ground at 87 deg. with a speed along the ground of less than 16 ft. per sec. Similar tests were made in France, and official records show a similar speed of vertical descent. In general, however, the landing of the Autogiro is made following closely the method of the birds. A glide is made which can either be flat, as that of an airplane, or considerably more inclined, at will, and, when a few feet off the ground, the pilot pulls hard on the stick, the nose goes up suddenly and the machine stops dead in the air like an automobile with powerful brakes, and falls gently, vertically, the tail skid touching the ground long before the wheels. The energy corresponding to the horizontal motion is partially dissipated in the braking action and partially stored in the rotary blades in the form of increased speed of rotation, contributing to the gentleness of the subsequent drop and landing.

The stability of the Autogiro is in itself perfect, since the resultant of the air reactions on the rotor passes always through a point, the center of the articulations, which is, in consequence, the metacenter, situated above the pericenter, which is the condition for stability. The restabilizing movement is always positive but its value is small. As a consequence, the machine is less sensitive to external disturbances while it proves more sensitive to the controls than an ordinary airplane, and this accounts for the extreme maneuverability of the Autogiro. On the other hand, special precaution is necessary if the automatic stability of the rotor itself is not to be impaired by the reactions on the fixed wings, controls, body, and other parts. Because of the articulated rotary blades, the

JUAN DE LA CIERVA

Autogiro has great flexibility in working under sudden loads or in bumpy air which gives it a much greater smoothness than the airplane under equivalent conditions. Structurally this is very important since the main load on the wings, which is centrifugal force, does not increase proportionately to the acceleration received, because of the great moment of inertia of the rotor, which opposes sudden changes in rotational speed. This seems to justify a lower load-factor in the Autogiro blades than in the equivalent fixed wings. As a mechanical structure, the Autogiro corresponds entirely to the flexible, yielding type, while the airplane is designed usually to resist the sudden accelerations, and this is, I believe, entirely to the advantage of the former. From the point of view of comfort, the difference between an Autogiro and an airplane is the same as that between an automobile without tires and one with modern balloon tires.

Take-off of the Autogiro

Until the latest type was produced, the take-off of the Autogiro was done by taxiing slowly around the flying field until the rotor, set in motion by the wind of the displacement, was rotating at something like 70 per cent of the speed of rotation in full flight, and then the pilot opened full the throttle. This process required a certain skill and was particularly painful and slow in calm weather. As a result of a research lasting almost a year, I have been able to develop and incorporate in the Autogiro a simple device which sets the rotor in motion while at rest and permits a take-off without more previous running than is necessary to impart to the machine the minimum horizontal speed at which it can maintain horizontal flight. That solution consisted in designing the tail in such a way that it can be set by the pilot with a considerable negative incidence, something like 70 deg. For structural reasons, it adopts the shape of a small biplane, the bottom plane of which acts as a fixed stabilizer, while the top one is the elevator. Two fins and two rudders at each end complete the tail.

To start the machine both surfaces are set upward and the throttle is gradually opened. The slipstream from the propeller is deflected so that when each blade in turn passes above the tail, it is deflected upward under the action of the strong current of air. When it moves out of that action, it

THE AUTOGIRO IN FLIGHT AT CLEVELAND

descends under its own weight and the centrifugal force, and in this manner a flapping motion is imparted to the blades which, as can easily be seen, is more or less equivalent to a current of air through the disc of the rotor, which accelerates more and more until the maximum speed of rotation is reached. Then the pilot releases the wheel brakes, adjusts the tail quickly to flying position and starts the run to take-off. The whole operation in calm air takes no more time than is necessary to warm up the engine, and about 80 per cent of the normal flying revolutions is obtained, which is enough for ordinary purposes.

Efficiency of the Autogiro and Airplane Compared

The efficiency of the rotory blades of the Autogiro, as compared with an airplane, has been very much discussed and has been questioned. I am in a position to say that this impression is unjustified, mainly because a distinction has not been made between unitary and total drag. A typical argument employed against the efficiency of the Autogiro is that when traveling between two given points, the rotary blades describe epicycloidal trajectories much longer than the straight line corresponding to the fixed wing. Therefore, it is argued that the energy employed must, of necessity, be greater.

The energy necessary to keep an airplane in the air is the addition of the induced power, dependent on the span, the total weight and the speed of displacement, and the frictional losses due to the profile drag. The same applies to the Autogiro and the induced power cannot be very different when the diameter of the rotor is about the same as the span of an equivalent airplane. However, the frictional losses, which are evidently greater per square foot of wing area of the rotary blades on account of the greater speed of displacement, need not be greater as a whole, in principle, since the total area of these blades can be, and is in practice, considerably smaller than that of the equivalent fixed wing.

Nothing can be found in pure theory to condemn the rotary free wings to an inferior efficiency. Even by assuming that an inferior liftdrag ratio is to be obtained always, the Autogiro can still be shown to be in a position to have better performances than the equivalent airplane because it is not submitted to the same limitations. The Autogiro has three fundamental parameters, diameter, wing area and pitch angle, whereas the airplane has only one, wing surface. An airplane must have a wing loading such as to give a good compromise in performance in speed, climb and landing, while in the Autogiro, the efficiency at high speed depends mainly on the actual blade-area, while the climb, minimum speed and landing depend principally, roughly speaking, on diameter and pitch, and it is possible and within reasonable limits to design a rotor having the utmost efficiency in all conditions.

Comparison with Airplane Unfair

In the present state of development, I think I can say that comparing the Autogiro with the latest airplanes, the result of 25 pears of intensive research by thousands of the best minds in the world, is not entirely fair. The present Autogiro is almost exclusively the result of my personal work and has already shown performance comparable with that of the equivalent conventional airplane. Its top speed is less than that of the best airplanes and a little more than some of the others. Its climb is somewhat less, but its angle of climb, which is far more important, is decidedly better, especially when geared propellers are used, in view of the fact that the best climbing-speed for the Autogiro is much lower than that of the airplane. The minimum speed is much slower and the landing qualities afford no possible comparison. In the future, I do not think it is a rash assumption to say that the Autogiro will reach speeds even higher than the airplane, because of its greater adaptability. In any case, it will not be inferior in that particular respect, while it will be superior on almost every other point.

The question has often been asked whether large machines could be constructed on the Autogiro principle. When considering an increase in the dimensions of the Autogiro, we can easily see that for two machines of equivalent wing-loading, the peripheral speed should be constant, and, admitting that everything is proportional, the centrifugal force on each blade will be in direct ratio to its weight and in inverse ratio to the dimensions, whence it follows that the centrifugal force will be proportionally less the bigger the machine. The consequence is that, contrary to the airplane, the limit in size seems to be determined by the stresses not increasing proportionally to the dimensions, which sounds paradoxical. But, while I am not now prepared to contemplate the design of very large Autogiros, I see no definite reason why they should not come in time.

The Future of the Autogiro

The advantages I claim for the Autogiro should make it superior to the airplane for nearly every purpose. Safety is not a negligible factor even for military or naval machines. Maybe some acrobatics that are easy to the airplane will not be so to the Autogiro, which will have other peculiar maneuvers of its own, but for observation, deck landing and similar maneuvers the Autogiro ought to be particularly advantageous.

Where the Autogiro will be of real help to the development of aviation is in the civil aspect, where safety is paramount. For carrying passengers, night-mail service and, especially, for private flight, the Autogiro is, I claim, the only existing practical solution of a flying machine. To fly the Autogiro without risk, only a few hours' training will be necessary, while it takes hundreds of hours to become a reasonably safe airplane pilot, and this quality alone should be enough to popularize flying.

In addition, the Autogiro will make possible the utilization of very small fields as landing grounds, and the present necessity of large airdromes obviously imposes an enormous handicap on the practical value of aerial navigation. The romantic roof landing is no longer a dream with the Autogiro and I hope that before very long we shall see Autogiro parking places in the middle of the cities.
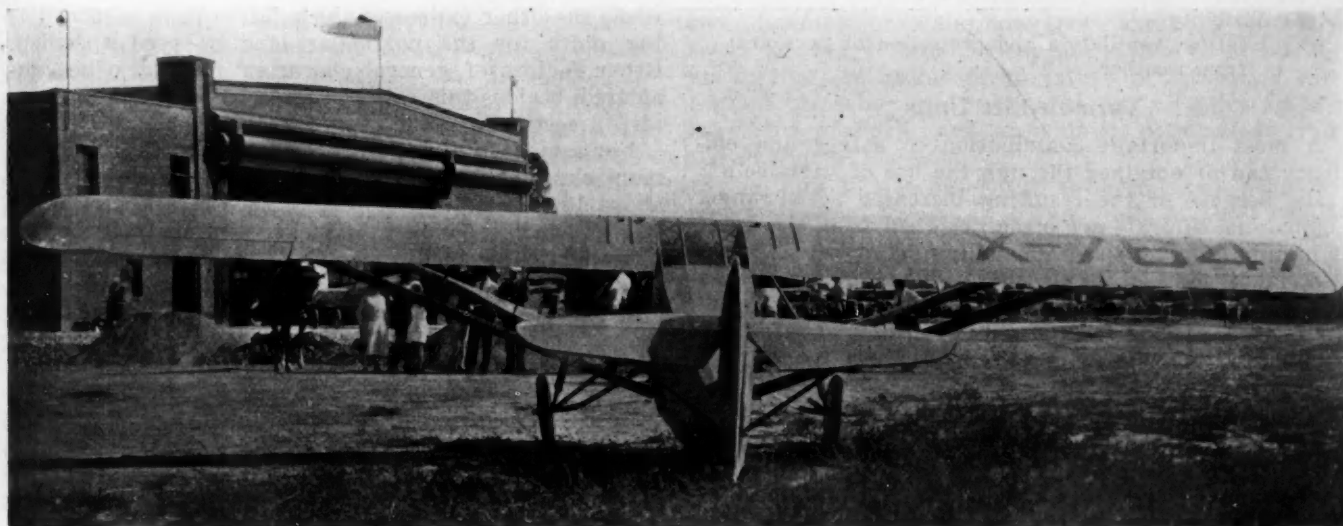
Possible Improvement of Present-Day Aircraft

By Heraclio Alfaro[1]

     Illustrated with CHARTS AND PHOTOGRAPHS

WHAT can be done to increase safety, efficiency and comfort in flight of aircraft now in use? In answer, the author describes several devices designed to bring about this result and supplements this with the results of wind-tunnel research. Detailed descriptions of the particular devices mentioned are not included, the object of this paper being to show the great possibilities of their use and the resulting improvement in performance.

Among the possible improvements mentioned are variable-lift units, lift-increasing mechanisms with particular reference to a flap developed by the author, an improved rolling control arrangement, locating the

tail surfaces out of the propeller slipstream to increase longitudinal stability, reducing the parasite resistance by special circular cowlings for radial engines and wheel fairings and the elimination of lift struts, better utilization of the available engine horsepower by employing a variable-pitch propeller, means for increasing drag when gliding and braking, protection against fire and better visibility.

Information concerning an experimental machine embodying some of the devices that the author has built supplements the discussion of the advantages of the different devices. This brief description is supplemented by performance data.

THE Daniel Guggenheim Foundation for the Promotion of Aeronautics has laid down what many authorities believe to be a very complete and well-balanced set of regulations covering, at the same time, safety and efficiency of modern aircraft. The requirements appear rather strict and probably could not be met by any of the present-day aircraft. Briefly, an aircraft is required to have a very high speed-range, a satisfactory response of all controls at any flying attitude, including flying angles above that of stalling, and a steep climb and glide to clear obstacles when taking off and landing from and into small fields, and, at the same time, it is required to carry 5 lb. of useful load per engine horsepower. Other needs of less difficulty of application are emphasized.

These requirements call for the possible incorporation

of all devices in hand that may mean any improvement in speed-range and efficiency. These, together with other points directly applying to safety, are summarized as follows:

(1) Variable-lift units
(2) Improved rolling control arrangements
(3) Improved means of longitudinal stability
(4) Reduction of parasite drag
(5) Better utilization of available engine horsepower in climb
(6) Drag increasing means when gliding and braking
(7) Fire hazards prevention

Including comfort is also believed to be pertinent, since it will result in an increase of safety because of the increased facility of operating the aircraft for long periods and under certain adverse conditions. Considerations for possible improvements of the following are then added:

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(8) Visibility

(9) Heating, ventilation and protection of personnel from weather

Variable-Lift Units

A most important contribution to safety and efficiency can be obtained through the use of variable-lift units, because of the resulting increased speed-range. Commercial aircraft are often designed from the point of minimum flying-speed or stalling speed, often called, also, landing speed. This speed should be as low as practically possible, and a compromise must be made with the desirability of obtaining, also, a satisfactory maximum flying-speed. It may be determined from the nature of the service required of the aircraft. If the available landing-fields are small and the prevailing weather is foggy, a low landing-speed may be advisable. The ability of the average pilot to land safely within a certain limit of speed is also a factor determining landing speed.

Most airplane accidents occur in landing, taking off and blindfold flying. In most cases the speed of the aircraft at the moment of a crash bears a very close relation to the minimum flying-speed, due to the fact that the pilot will attempt flying at as low a speed as possible, provided the controls are responsive, when the visibility is poor and when landing, and because, also, he is forced to fly slowly when climbing steeply. In the event of a crash, the impact is therefore likely to occur at a speed bearing some relation to the stalling speed. Modern aircraft are expected to have suitable responsiveness to the controls at all flying velocities, and at velocities above stalling the pilot is probably capable of avoiding the crash by using the controls. These assumptions are somewhat liberal if considering a quantitative value of the effect of stalling speed on safety, but they can lead to useful considerations of the relative effect of speed on the safety of the flying personnel.

Personal injury in a crash is due to impact. The force of impact is proportional to the square of the velocity, which in this case can be assumed to be the stalling velocity of the aircraft.

In the basic equation for steady flight,

$$\text{Weight} = \text{Lift} = L_c A v^2$$

the weight and the area A are constant, and the lift coefficient L_c varies inversely as the square of the velocity v. Therefore, we can write a relative expression of safety.

$$\text{Safety} \propto F_i \propto v^2_{min} \propto 1/L_{c\ max}$$

in which F_i is the force of the impact. This expression shows the advantage of using wings whose maximum lift-coefficient is high.

To effect a compromise between efficiency and safety, the maximum speed obtainable must be high so that the advantages of flight may be benefited, and henceforth the need of a large speed-range. For speed, a low relative drag is required for all parts in the lifting units to provide for the best combination of efficiency and safety. Employing wing characteristics that could give the highest possible ratio of maximum lift-coefficient to minimum drag-coefficient, $L_{c\ max}/D_{c\ min}$. The first term controls the area of the wings,

[2] See Airplane Design, by Edward P. Warner, chapters 4, 5 and 6.

[3] See National Advisory Committee for Aeronautics Technical Note No. 270.

[4] See National Advisory Committee for Aeronautics Technical Note No. 297.

while the other expresses the relative drag of the lifting units for the particular landing-speed specified. Other factors of general character[2] must also be considered, besides this ratio, in the selection of the proper airfoil section.

For a modern airfoil of medium thickness, the maximum obtainable value of this ratio could not go much above 150 for an aspect ratio of 6, Clark-Y section at High Reynolds Number[3]. Thicker sections may be anticipated to have a larger $D_{c\ min}$ in spite of having, possibly, a retarded burble point, and consequently, a larger $L_{c\ max}$; and thinner sections, although they will have a smaller $D_{c\ min}$, will generally have a lower $L_{c\ max}$. The profile or viscous drag of such medium thick wing sections is very low for all flying angles.

Apparently, little will be gained in efficiency in future research on wing shapes alone. In safety, though, a gain may result by obtaining a smoother top of the L_c curve, and consequently, a delay in stalling, a reduction of spinning tendencies and an increase in lateral control effectiveness at high angles[4]. Research along this line probably will be undertaken with an aim to obtaining the mentioned advantages without sacrificing efficiency.

At this time the most practical way to improve the efficiency factor of wings as expressed by the ratio $L_{c\ max}/D_{c\ min}$ apparently is through the use of accessory devices working in conjunction with the main wings to increase the first term of this ratio. For many years continual attempts have been made to accomplish it in a useful way. In the early designs, the increase in weight and mechanical complications was seldom justified by a sufficiently high gain in the value of this efficiency factor. In other cases obtaining a satisfactory lateral control at angles of attack near or above the stalling angle was found difficult.

Lift Increasing Devices

At present several lift increasing devices that are considered successful have been applied to aircraft. The most elementary of these is the plain aileron type of flap. The L_c increase in this case ranges from 40 to 50 per cent for flap angles and flap widths within practicable limits. This percentage varies, also, with the wing section used. Thus, for a wing with a low $L_{c\ max}$, the per cent increase may be larger than for one with a high maximum value of the L_c. In a medium-thick wing section of good efficiency, Clark-Y, the increase would not go above 55 per cent for a flap width of 28 per cent of the wing chord and 45-deg. flap angle. In practice, such a wing requires means of lateral control. One of the proposed types regulates the relative angular deflection of the flap on one side as compared to that on the other, for any setting of the mean angle of the whole flap, so as to obtain a different increase of lift in one wing, as compared to the other, according to the degree of rolling control desired. This may result in dangerous yawing moments and rotational instability, with the corresponding spinning tendencies. To overcome this difficulty, a sacrifice is made in the maximum value of the lift coefficient obtainable by using only part of the flap as such, and the rest, near the wing tips, as ailerons. In most cases this would cut the possible $L_{c\ max}$ increase to approximately 60 per cent of its previous obtainable value, so that with this arrangement the practical gain is in the neighborhood of $0.60 \times 0.45 = 27$ per cent.

With the Clark-Y wing having an $L_{c\,max}$ of 0.0038 at high Reynolds number[5] the figure becomes 0.0048. For a wing loading of 9 lb. per sq. ft., the landing or minimum possible flying-speed drops from 48.5 to 43.5 m.p.h., a reduction of 5 m.p.h. The impact pressure would have decreased 27 per cent, increasing, therefore, substantially the safety from injury to personnel in case of a crash. Whether at high Reynolds number the per cent increase in $L_{c\,max}$ is maintained is not yet certain but, at any rate, a consistency in the relative value of the results may be reasonably anticipated.

One of the most popular types of lift increasing devices is the Handley Page-Lachman slotted wing. The main virtue of this device consists in a retardation of the burble point. The lift-coefficient curve is, therefore, extended through several degrees of angle, and the maximum reaches a higher figure. The same virtue of this device allows the flow to remain relatively streamlined up to higher angles than usual and facilitates proper aileron response at high angles. Also, the use of a flap improves the efficiency of the device by virtue of this smoother flow, bringing the $L_{c\,max}$ to still higher figures. Values up to 0.00742 have been obtained for the value of $L_{c\,max}$ with extravagant sizes of the auxiliary airfoil in the front end of the flap.

With a Clark-Y wing in which the slot and flap sizes were of more practical dimensions, the $L_{c\,max}$ at low Reynolds number was 0.00486 at an angle of attack between 17 and 18 deg., an increase of 50 per cent. The large angle of attack is considered as a substantial handicap for landing. The landing speed could be reduced from 52.7 to 43.0 m.p.h. for the same wing loading as before. However, the requirements of satisfactory lateral control and reduction of spinning tendencies may necessitate a decrease in the maximum efficiency of the device. Spinning tendencies of an airplane provided with automatic slots seem to be eliminated. In this arrangement the slot is adapted directly in front of the ailerons only. Whether the same virtue will manifest itself, however, when the flap and non-automatic slot are used in the whole span and the flying angle is above that corresponding to maximum lift for the slot-flap wing-combination remains to be seen. The automatic slot, if used along the whole span, may eliminate this difficulty, since it would remain open in the inner wing and closed or partly closed in the outer. Providing independent operation of the automatic slot in independent sections along the span may prove advantageous.

The tail-spinning tendencies of a wing section depend exclusively on the shape of the top of the L_c curve, and a flat-top L_c curve will indicate little if any tendency to spin. Most wings provided with moderate sized slots, either automatic or of the manually operated type, probably will show no tendency, or at the worst a very small tendency, to spin.

The lift increase in the slotted-type wing is due to a delayed stall resulting from a tendency of the flow to follow the upper face of the wing more closely instead of breaking away from it at the usual stalling angles of the plain wing. Wing sections with a very large camber possess much the same virtue. The Gottingen 244 thick section has an $L_{c\,max}$ of 0.0046. Its top also is substantially flat with the corresponding reduction of autorotational or tail-spinning tenden-

cies. Bending down the flow above the wing smoothly seems necessary, either by the slot system or by having an appropriate radius of curvature in the upper surface of the wing, which changes the direction of the flow more gradually and prevents its detachment from the contour of the wing.

The thick section described, however, has a poor efficiency, because its $D_{c\,min}$ is very high, and the resulting efficiency ratio is very low. Therefore, a variable camber wing may give at least as high maximum L_c as the slotted type or the thick cambered wing, with nearly as low minimum D_c as the original basic wing and also with a flat top L_c curve.

To compare better the advantages of the various lift increasing devices, they should be applied to the same type of wing, the flap supports or slot gaps and the like should be taken into account for their effect on the minimum drag. The increase of weight of one type as compared to another should be divided by the wing loading, and the result would represent additional square feet of wing required for a required landing-speed. The drag of this additional area should also be added to the minimum, placing the heavier type at a disadvantage.

A type of flap developed by me, in which the flap travels backward at the same time that it is folded down, has given satisfactory results and is mechanically simple and relatively light. The development was based on the assumption that a hinged flap of practical size could increase the $L_{c\,max}$ value 45 or 50 per cent, and that if moved backward at the same time as downward, an extra increase of the total lift would be obtained, due to the increase in the chord. A simple system of linkage was worked out by which an increase of about 22 per cent in the chord was possible. The total lift, therefore, was

$$1.22 \times 1.50\,L_{c\,max} = 1.83\,L_{c\,max}$$

The Clark-Y wing tested at atmospheric pressure has an $L_{c\,max}$ of 0.00325, which should then become 0.00595.

Wind-tunnel tests made in Europe as early as 1923 showed an increase of 87.5 per cent in the maximum lift-coefficient with a true value of 0.00575. In these tests the flap width was 22 per cent of the wing chord, and the flap angle 57 deg. The maximum value of the L_c was obtained at a 14-deg. angle of attack. These tests proved consistent with the original assumptions and were encouraging. The controls of the flap were linked so that the reaction on the operating levers was a small fraction of the corresponding reaction that would otherwise be found if the aileron type of flap were used. This reaction increases gradually as the flap is brought down. Later tests at the Massachusetts Institute of Technology also showed substantial consistency with the early ones. At that time an investigation was made, also, on the air loads on the flap for different angles. This showed that under the worst conditions, the usual trapezoidal loading could safely be assumed for design purposes and that an average of 20 lb. per sq. ft. for 100 m.p.h. speed and maximum-load condition is a satisfactory figure. For airplanes with 10 lb. per sq. ft. wing loading, the flying velocity anticipated with flap down was estimated as not exceeding 50 m.p.h. although it could be safely brought up to 120. This corresponds to 4.5 lb. per sq. ft. and a design load as specified for ailerons would be safe. For a first design, however, a large margin of safety would be used to

[5] See National Advisory Committee for Aeronautics Technical Note No. 270.

meet any emergency in case of fluttering or vibration of the flap.

A machine was designed, therefore, to test the efficiency of this device in full size. Previous to starting construction, additional wind-tunnel tests were run to ascertain the actual figures for the particular type of wing tip and flap span used and also to study different types of rolling control in combination with the flap.

Wind-Tunnel Tests of Wing and Flap Combinations

Two wings were tested, the National Advisory Committee for Aeronautics M-6, and the Clark-Y, with two different types of flap. One was the usual aileron type and the other the sliding flap developed by me and characterized by the two Greek letters $\alpha\rho$ due to their phonetic similarity with my name. Tests were also made with the flap and a leading edge or nose extension applied simultaneously to the Clark-Y section. The results obtained are plotted in Fig. 1 together with those of Handley Page slotted wings and are listed in Table 1. Wings 1 to 6 inclusive were tested at the Guggenheim School of Aeronautics in New York City, while the test of Wing 7 was made in Cuatro Vientos, Madrid, Spain, all the models having an aspect ratio of 6. Wings 3, 4, 5 and 6 had rounded tips, and the flap covered only 0.886 of the span. The area having the flap immediately behind was 0.902 of the total.

The square tips cooperate to a great extent in increasing the maximum L_c due to having higher local pressures[6]. For the sake of closer comparison, a correction has been made. The gain in $L_{c\,max}$ has therefore been divided by 0.902, added to the $L_{c\,max}$ of the normal wing and listed under "Comparative Increase" for Wings 3, 4, 5 and 6. The effect of increasing the aspect ratio on the L_c curve of any wing is to increase its $\delta L_c/\delta\alpha$ and also slightly its $L_{c\,max}$. Corrections should be made for wing tip loss, if rounded, by reversing the previous process. Using a standard shape of rounded tip, an increase of aspect ratio will increase the percentage of wing area immediately followed by a flap. This will slightly increase the $L_{c\,max}$ as compared to the value for an aspect ratio of 6 having the same standard shape of tips.

The Handley Page flap width was 25 per cent of the wing chord, the aileron type of flap was 28 per cent wide, and the $\alpha\rho$ flaps were only 22 per cent wide. The angle of attack of maximum lift with the Handley Page arrangement in both cases was between 17 and 18 deg., while with the $\alpha\rho$ flaps it was 12 deg. for Wings 4 and 5, 16 deg. for Wing 6, and 14 deg. for Wing 7.

While the tests of the $\alpha\rho$ arrangement were not car-

[6] See National Advisory Committee for Aeronautics Technical Note No. 288.

ried much above the stalling angle, we could see that the top of the L_c curve was smooth and flat, and the spinning tendencies would therefore be small, if any. Considering these results, several of the combinations tested were decidedly superior to the Handley Page slotted wing. The angle of maximum lift is smaller and closer to practical flying angles. The $L_{c\,max}$ is substantially higher, 1.21 times, for the same wing. The Handley Page wing has nose and flap mechanisms, while most of the other wings have the flap exclusively and appear, therefore, to be simpler, mechanically. Of these Wings 5 and 6 were considered by far the most suitable. The test of Wing 7 was made under different conditions, and the $D_{c\,min}$ for this wing is higher than that of the Clark-Y, and therefore the efficiency would be rather low. For a first full-size model we decided to use the $\alpha\rho$ flap alone, which corresponds to Wing 5, to simplify the problem mechanically.

All the types of flap described are adaptable for application of automatic control; that is, all of them show the air load to have a steady and consistent tendency to increase when the flap angle is increased. The Handley Page slot was shown to be particularly simple in this respect. However, if the automatic control is applied also to the rear flap, an auxiliary spring attachment probably will be required. This does not necessarily increase the complication or weight excessively but does approximately, as it would in any other type of automatically operated flap. In the $\alpha\rho$ type, the moving parts required would be relatively light, due to the lighter operating-loads found for the particular linkages used.

Some advantages will result from automatic operation, but manual operation of the flap would also be desirable for some cases in combination with the automatic mechanism. The automatic control device would contain a single spring tending to pull the flaps down, a hand control to operate the flap against the pressure of the spring, when and if desired, and possibly a damping oil cylinder to avoid sudden motions of the flap and oscillations. The flap had to be supported at different points and controlled, also, at various locations. All control points were connected to assure simultaneous action throughout, and the control was attached at a single point in the flap controlling system. The flap was operated manually in this first model, thus eliminating the additional spring and oil-cylinder combination. Preliminary tests could be made in this fashion and valuable data collected to determine the spring and oil-cylinder arrangement contemplated for the final design. The device could be used, also, as a semi-automatic one, in which the spring would overcome the majority of the load necessary for manual operation.

TABLE 1—TESTS OF SEVERAL DIFFERENT AIRPLANE-WING SECTIONS

| Wing No.	Arrangement	Actual $L_{c\,max}$ Normal	Actual $L_{c\,max}$ Flap Down	Increase in $L_{c\,max}$ Actual	Increase in $L_{c\,max}$ Per Cent	Comparative Increase, Per Cent	$L_{c\,max}$	$D_{c\,min}$	$L_{c\,max}/D_{c\,min}$
1	M-6 Wing with Handley Page Slot and Flap	0.00251	0.00438	0.00187	74.5	74.5	0.00438	0.000028	156
2	Clark-Y Wing with Handley Page Slot and Flap	0.00324	0.00486	0.00162	50.0	50.0	0.00486	0.000037	131
3	Clark-Y Wing with Aileron Type of Flap	0.00311	0.00483	0.00172	55.2	61.3	0.00502	0.000037	136
4	M-6 with $\alpha\rho$ Flap	0.00255	0.00497	0.00242	95.0	105.0	0.00523	0.000028	187
5	Clark-Y with $\alpha\rho$ Flap	0.00317	0.00561	0.00244	77.0	85.2	0.00588	0.000037	159
6	Clark-Y with $\alpha\rho$ Flap	0.00317	0.00631	0.00314	99.0	112.1	0.00665	0.000037	180
7	Gottingen 436 with $\alpha\rho$ Flap	0.00336	0.00615	0.00279	83.0	83.0	0.00615	....	...
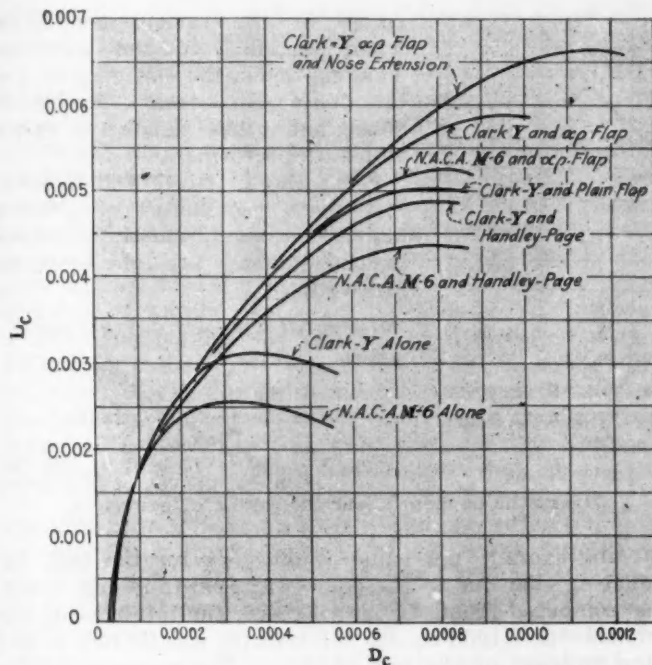
FIG. 1—COMPARATIVE TEST-RESULTS OF LIFT-INCREASING
DEVICES

The Wings Tested Were the Clark-Y and the National Advisory
Committee for Aeronautics M-6 with and without Handley Page
Slotted Wings, the Regular Aileron Flap, a Special Flap and a
Nose Extension

Alternatively, a handle could be used to vary the tension
of the spring on a manually operated mechanism. For
simplicity the extensible nose for either automatic or
controlled operation was not used in this first machine.
The nose extension could be used in combination with
a plain wing alone or with any flap-wing combination.

Improved Rolling Control Arrangement

This problem calls for effective operation at all angles
of flight, including those above maximum lift. In emer-
gencies and in some special cases aircraft, in the near
future, will be required to land in a stalled condition.
This cannot be practically obtained until suitable lateral
control is obtained above stalling angles. At the same
time, designing the rolling control so that the yawing
moments generated by its operation would be small
and, preferably, opposite to those usually found today
with the aileron type of control will be most desirable.
Another valuable feature would be to separate the
lateral control surfaces from the trailing edge of the
wing, allowing them a whole span flap.

These three requirements are to a great extent satis-
fied by the spoiler type of rolling control. Spoilers
provide powerful rolling control at almost any large
angle of attack, and their effectiveness extends to angles
of attack well above that of stalling. The yawing mo-
ment is reversed from usual practice and tends to safe
and effective response of the rolling control. At low
angles, however, the spoiler is very ineffective. To
overcome this difficulty, a combination of spoilers with
wing tip ailerons is considered satisfactory. Wing tip
ailerons of moderate size can give a fairly high rolling
moment at high speed. Their effectiveness decreases
with reduction of speed, however, but, as the action of
these ailerons decreases, the power of the spoiler in-

creases, resulting in a satisfactory effect from the com-
bination.

Fig. 2 shows curves of rolling moments for a spoiler
of moderate size tested in combination with an 8 x 48-
in. Clark-Y wing model with the extensible nose and $\alpha\rho$
flap fully depressed. The spoiler had a span equal to
24 per cent of that of the wing, could be rotated out-
wardly and vertically 2 per cent of the wing chord and
was placed at 15 per cent of the chord from the leading
edge of the wing section. In the direction of the span
the spoiler's length did not start at the wing tip but at
34 per cent of the chord measured inward from the tip.
Testing the wing tip ailerons was not considered neces-
sary since their moments could be computed mathemati-
cally with sufficient accuracy. The possible error that
may occur in this case will correspond to large angles
of attack where most of the control is obtained from the
spoiler action and is larger than required.

The coefficients used in Fig. 2 have been obtained
from the following expression:

$$C_L = L/qSb$$

where
    b = the span
    C = the rolling-moment coefficient
    L = the total rolling-moment in foot-pounds
    q = the impact pressure
    S = the wing area in square feet

Another form of rolling-moment coefficient in which
the weight W of the machine enters as a factor, is

$$C_L = L/qWb$$

Practical observation and tests have shown that for 10
deg. aileron deflection and 0 deg. angle of attack,
when $C_L = 0.0060$ or higher, the control is satisfac-
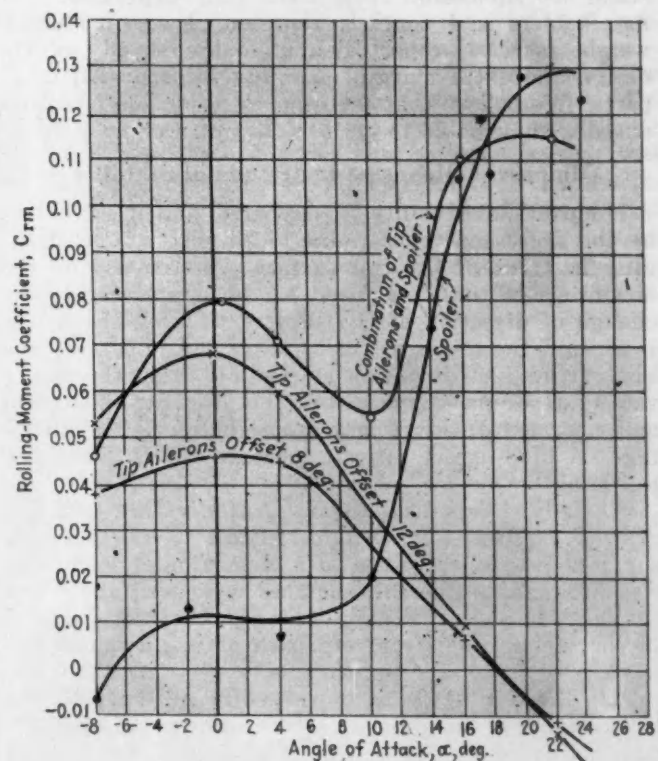tory. For these conditions of angle of attack and

FIG. 2—ROLLING-MOMENT CURVES

The Curves Were Obtained from Tests of a Moderate-Size Spoiler
Alone and in Combination with Tip Ailerons in a Clark-Y Wing

aileron angle, Fig. 2 shows a value for the coefficient of 0.0054. At higher angles of attack, the efficiency is much better than in any aileron type control. The full-scale airplane built has a still larger rolling control than that from which the test results plotted in Fig. 2 were obtained. The spoilers are larger and ample lateral control is therefore provided. The foregoing rule for satisfactory control applies only to the aileron type of control. The spoiler and aileron arrangement can probably afford a smaller coefficient due to the favorable yawing moment and to its efficiency at high angles.

FIG. 3—RELATION OF THE EFFECTIVE DOWNWASH ANGLE TO THE ANGLE OF ATTACK

With the first set of wings, the lateral control used was a combination of very small ailerons and spoilers. The area of the ailerons was 10.30 sq. ft. or only 6 per cent of the total wing area; the spoilers were 2 x 36 in. when fully exposed, which is about one-half of the area of the spoilers used in the final set of wings. In flying tests, great effectiveness was found at large angles. At flying angles of more than 30 deg. good response was observed, although the control was somewhat slow in action, which was attributed to the larger damping in roll due to the large aspect ratio used, 7.7. We decided to use more powerful means in the next set of wings. In this set the aileron action was considered satisfactory, as far as it could be predicted from tunnel tests.

This final set of wings with the $\alpha \rho$ type of flap and lateral control was approximately 65 lb. heavier than without the flap. The beams had to be stronger to withstand the tip-aileron loads when fully depressed. The flap holders and controls represented a considerable weight increase, especially due to the novelty of the design and extra margin of safety incorporated in all parts. We believe that the same design could be reproduced with some 20 to 30 lb. saving in weight.

Improved Means of Longitudinal Stability

Longitudinal stability is hampered to a great extent by the decreased velocity due to all obstructions dragging in front of the tail surfaces, partly also by the downwash of the wings, and partly, again, due to the change of direction of the slipstream when the power is on and the angle of attack is varied. Locating the tail surfaces as far away as possible from the downwash path of the wings, out of the propeller slipstream and clear out of any forward obstruction is an advantage. A high aspect ratio to increase the $dL/d\alpha$ of the tail is also desirable.

To study these effects in conjunction with a fully depressed $\alpha \rho$ flap, a wind-tunnel model having the tail surfaces located above the path of maximum downwash was built. Thus the tail surfaces were well above the fuselage and clear of any forward obstructions and farther than usual from the path of maximum downwash.

The effective angle of downwash ϵ at the tail was plotted against the angle of attack showing an approximate $d\epsilon/d\alpha$ of 0.3 for 0 deg. of attack. This curve is shown in Fig. 3. The tail effectiveness is usually assumed equal to the ratio of $dL_c/d\alpha$ for the tail surface alone out of interference in free air to $dL_c/d\alpha$ as af-
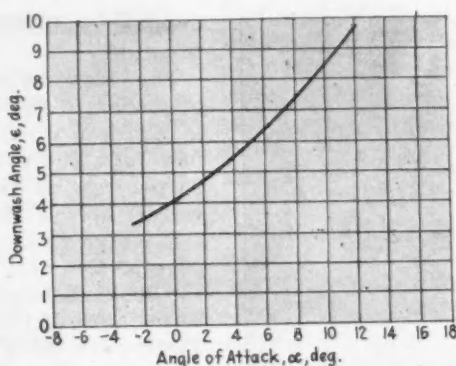
fected by the various conditions when installed in the airplane. This expresses the efficiency of the tail due to its location, downwash effect and other handicaps under which it performs.

Since the L_c curve and moment M_{cg} about the center of gravity plotted against the angle of attack are substantially straight lines, we can write

$$dL_c/d\alpha_{tail} = (dM_{cg}/d\alpha)\ (1/A_t v^2 l)$$

where

A_t = the tail area
α = the angle of attack
L_c = the lift coefficient
l = the lever arm of the tail about the center of gravity
M_{cg} = the moment about the center of gravity
v = the velocity

The average net value of $dM_{cg}/d\alpha$ for the tail, deducting that due to the body, was 1.60 in-lb-deg. units, as computed from the tunnel tests; the tail area of the model was 0.1938 sq. ft., the velocity was 60 m.p.h. and the leverage of the tail 14.65 in. The computed value in miles per hour, pounds, square foot units is therefore

$$dL_c/d\alpha_{tail} = (1.6 \times 12)/(12 \times 0.1938 \times 3600 \times 14.65)$$
$$= 0.0001565$$

The aspect ratio of the tail surface was 3.8. The average value of $dL_c/d\alpha$ taken from the various airfoils of this aspect ratio is 0.0001745. The tail effectiveness is therefore, 1565/1745, or 90 per cent. This is unusually high and may be due to the increased circulation resulting from the presence of the flap and the particular location of the tail surfaces being substantially in a region of higher wind velocity and free from obstructions. We decided to use this type of stabilizer since its additional complications were unimportant as compared to the increased efficiency.

In actual flying tests the responsiveness and stability were very good in spite of the relatively short tail. At an angle of more than 30 deg. with the horizontal and the power off, in which condition the airplane was far above stalling angle, the response of the elevator was excellent. Small fore and aft motions of the stick brought immediate pitching accelerations. The same result was observed with the rudder and was believed due to its large aspect ratio, freedom from forward obstructions and continuity of lines with the fuselage and fin. The arrangement of the tail surfaces is shown in Fig. 4.

Reduction of Parasite Drag

To obtain higher speed, rather than to increase the power available, all efforts should be concentrated toward reducing the parasite drag in all parts. Among these, the projecting engine parts, the landing-gear wheels and the effects of interference are considered as most promising for improvement. The speed varies inversely as the square root of the drag, or rather as a root slightly inferior to the square. On the other hand, it varies as the cube root of the engine horsepower. Experience has shown that very little gain in speed is obtained by increasing the horsepower if the parasite drag is also increased by the use of the larger power-plant and its accessory parts. On the other hand, a

reduction in the drag helps to increase the speed materially.

Considerable progress has been made in the streamlining of modern airplanes. However, certain parts have been neglected in that respect, perhaps due to the increased weight and cost, or perhaps due to routine used in design of lower-speed obsolete aircraft. The increased reserve power of modern designs has increased the high speed of airplanes to an extent where a saving in parasite drag is a higher proportion of the total and is worthwhile even if it carries with it some increase of weight.

For a long time, the importance of cowling radial air-cooled engines to reduce the drag of being emphasized. Early British tunnel tests showed that cylinder-heads caused enormous disturbance in the flow and large drag. Recently the tests made by the National Advisory Committee for Aeronautics[1] present one of the most interesting disclosures leading toward increasing efficiency of aircraft. The facts were felt to a certain extent, but figures as to the exact amount of drag in full scale were unknown. The addition of proper cowling increased the speed of a single-seat fighting airplane from 118 to 137 m.p.h. Although the arrangement of this particular design lent itself to substantial improvement in decreasing the air resistance, in almost any case the new cowling will pay for itself many times either in power saving for a given speed or in gain of speed for the given power.

Landing-gear wheels represent a large proportion of the parasite drag of an airplane. Many times they come immediately behind the slipstream and count for a still greater increase in drag. The usual wheel fairing is sufficient to reduce the drag to some extent but the interference between the wheels and the other land-

[1] See National Advisory Committee for Aeronautics Technical Note No. 301.

ing-gear members is great. Covering approximately two-thirds of the height of the wheels with an aluminum fairing that would protect three-fourths of the wheel and the vertical compression strut on each side would be an advantage. Wind-tunnel tests on these fairings are not available now, but a substantial gain in speed for the weight and cost involved can be anticipated.

In airplanes where the wheels are near the plane of rotation of the propeller the effect of the drag of the wheels reduces somewhat the velocity directly in front and causes a fluctuation in the inflow velocity of the propeller for every revolution, which may reduce efficiency.

These fairings can be designed to act also as mudguards, and, in this way also, the piling of mud on the lower wing panel or struts of the airplane can be avoided. This may slightly increase the practical cruising speed. Mud projection to the propeller when taking off will be also avoided, with its corresponding saving in service cost and the resulting gain in propeller efficiency after some time of service.

Since the success of Colonel Lindbergh's flight and that of Chamberlain and Levine, lift struts became very popular among designers of high-wing monoplanes. A substantial increase in the maximum lift obviously could be obtained with almost no additional drag at low angles and a very slight increase of weight. In the design mentioned earlier in the paper, I followed a similar reasoning and decided to use lift struts for the wing bracing, running some wind-tunnel tests, however, to determine its merit since the additional complication and weight were worthy of consideration.

In the model the wing area was 1.356 sq. ft., while that of the struts was 0.41 sq. ft.; the increased area due to the struts was therefore 30 per cent, which seemed
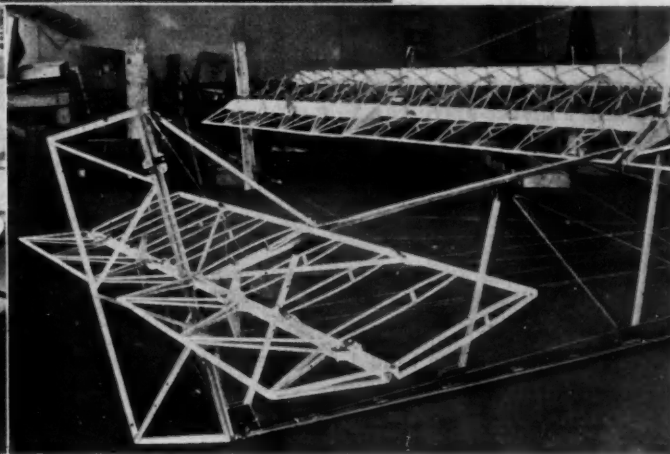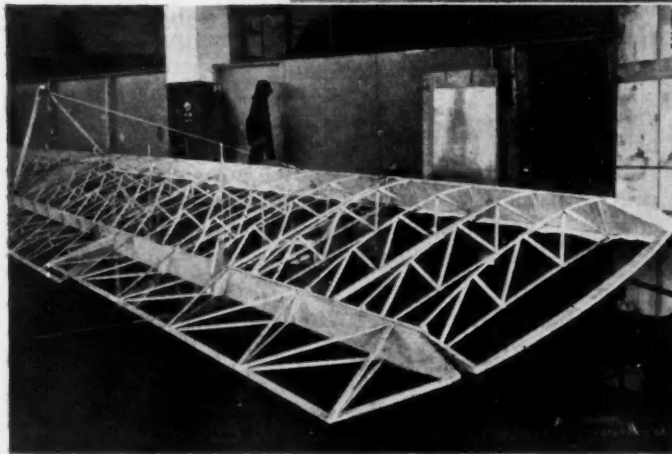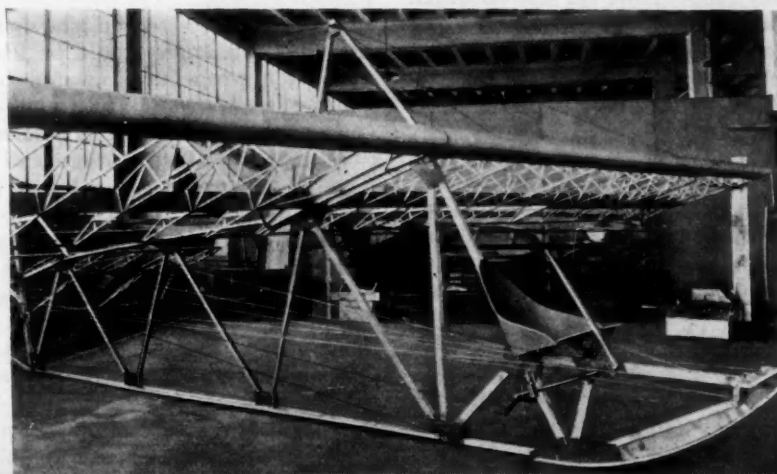

FIG. 4—DETAILS OF THE AIRPLANE BUILT BY THE AUTHOR

very promising. The section of the struts was double cambered with about twice as much camber in the upper as in the lower face of each strut. The maximum lift of the model with body wing and struts was 15.02 lb. against 14.55 lb. for the body and wing alone. The difference was therefore 0.47 lb. and the computed coefficient due to the effect of the struts alone and in the usual units was

$$L_{c\ max} = P/Av^2$$
$$= 0.47/(0.41 \times 3600)$$
$$= 0.000318$$

This is about one-tenth of the corresponding coefficient for the struts alone, if they were acting as an independent wing. It was estimated that the complication and weight added did not justify at all its use. Apparently the proximity of the wing reduces the strut lifting effect.

The drag difference, with and without struts, at the normal flying angle, 0 deg., was 0.03 lb., which corresponded to 0.0000208 in the coefficient, a very small figure, considering the relative thickness of the strut section used. The effective ratio of $L_{c\ max}/D_{c\ min}$ of the struts was 15.3; a very low figure of efficiency. While the drag measurements may be subject to some error due to the small difference between two relatively high figures, the effects of interference tended decidedly to affect the lift rather than to increase the drag.

Here again we may credit the relative circulation. Under the wing the velocity is lower than normal, especially at high angles, and substantially also at cruising angles. This was probably responsible for the observed drop of drag and, together with the shielding effect of the wing, for the great reduction of $L_{c\ max}$. The idea of using lift struts was abandoned. Several manufacturers are known to have taken a similar attitude.

Better Utilization of Available Engine Horsepower

The immediate apparent improvement of modern aircraft as far as it concerns engine-horsepower utilization calls possibly for geared propellers and decidedly for variable-pitch propellers. This necessity becomes almost obvious when considering the possible increase in performance in climb, in taking off with heavy loads and in clearing obstacles climbing out of small fields.

The horsepower investment of a modern aircraft powerplant using a conventional type of propeller may be analyzed from various experiments and computations. A typical example is shown in Table 2 for the sake of comparison. These items are plotted in full lines in Fig. 5 for a machine whose speed-range is 2.8. In this machine the maximum climbing-speed is 1.4 of the minimum flying-speed.

Using a direct-drive variable-pitch propeller, the pitch of the blades can be adjusted during flight accordingly, so as to maintain constant engine-speed. The approximate horsepower investment then would change as shown in the second column of Table 2, and is plotted in dash lines in Fig. 5.

The numerous advantages of the variable-pitch propeller can be seen from a study of Fig. 5, and summarized as follows:

(1) A gain of more than 1 per cent in the maximum speed of the airplane. This, in practice, may be still larger, especially when referred to the practical cruising speed.

(2) A gain of 13 per cent in the total efficiency when climbing, which represents a 33.3-per cent in-

crease in the available horsepower for climb and nearly the same percentage of increase in climbing speed.

(3) An enormous gain in the maximum climbing-angle. This is of the utmost importance especially for commercial aircraft to clear obstacles that may hamper the usefulness of small fields.

The climbing angle is approximately expressed by $\sin^{-1}v_c/v$, in which v_c is the climbing speed. In the case shown, the flying speed for the best climb has been reduced from 1.4 to 1.2 times the stalling speed, v_{stall}, while the climbing speed was increased 33 per cent. The climbing angle was then considerably increased. Taking as an example an airplane with fixed-pitch propeller

TABLE 2—APPROXIMATE RELATIVE PERFORMANCE OF FIXED AND VARIABLE-PITCH PROPELLERS IN PERCENTAGES OF ENGINE HORSEPOWER FOR A TYPICAL AIRPLANE

Item[a]		Fixed Pitch	Variable Pitch
1	Minimum Loss Due to Propeller	18.0	17.0
2	Loss Due to Decrease in Propeller Efficiency When Climbing	3.5	4.5
3	Loss Due to Decrease in Engine Speed When Climbing	14.0	0.0
4	Loss Due to Slipstream Velocity Increase When Climbing	3.5	4.0
5	Power Required To Fly at Climbing Speed	22.0	19.0
6	Power Available for Climb	39.0	55.5

[a] The numbers in this column correspond to those on the vertical lines at the left of Fig. 5.

in which $v_{stall} = 40$ m.p.h. and $v_c = 800$ ft. per min., the climbing angle would be 9½ deg. and with a variable-pitch propeller it would become 14½ deg. This represents approximately a 35-per cent saving in the space required to clear obstacles when taking off.

A substantial advantage can also be obtained from gearing down the propellers. However, with the propeller efficiencies found today for the engine speed used, the gain may not be as great as is shown for the variable-pitch propeller. The weight increase may be, very closely, the same in both cases. The resulting mechanical complications are within the reach of the art, and its cost is paid many times in efficiency.

A number of successful designs are now available and satisfactory service tests have been recorded for both geared and variable-pitch propellers. In the last few years several successful variable-pitch propellers have been tested, both here and abroad, and all reports show considerable success. The adjustment mechanism can be made simple, reliable and easy to operate. Most designs have been very encouraging from the beginning, and practically all can be brought to success after the usual experimental stage. The combination of both, reduction gear and variable-pitch propeller, will naturally still increase the utilization of the engine horsepower. Their advantages, however, overlap in some cases so that the gain obtained for each one independently cannot be added together when both are used.

Drag Increasing Means When Gliding and Braking

To make a landing, obstacles have to be cleared near the boundary of the field in most cases, which, of necessity, reduces the available space left to accomplish a safe landing. In the case of a forced landing, high obstacles surrounding a field become a serious hazard. To use the available landing-fields most efficiently, ability

to glide at a steep angle with relatively low flying-speed would be desirable. In the regular type of airplane the gliding angle is usually small, 5 or 6 deg. If this angle is increased, the flying speed also increases considerably. In a landing, the approach is usually made at low speed so as to cover as short a space as possible on the ground. The angle of glide is approximately expressed by $\tan^{-1} D/L$, where D is the total drag of the airplane at the attitude considered and L is the net lift. The latter is considered equal to the gross weight of the airplane, and any change in its value would produce a vertical acceleration. The drag in airplanes usually is subject to a definite rule, which may change substantially with each design. Any increase in D certainly increases the angle at nearly the same rate for the small angles used.

The $\alpha\rho$ wing flap serves to increase not only the $L_{c\ max}$ but also the D_c, and therefore the gliding angle.
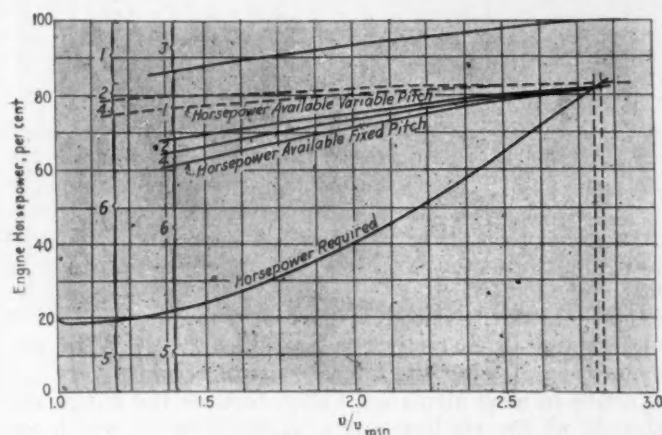
FIG. 5—RELATIVE PERFORMANCE OF FIXED AND VARIABLE-PITCH PROPELLERS

The Numbers on the Bracketed Vertical Lines at the Left Correspond to Those in the First Column of Table 2 Designating the Different Divisions of the Engine's Horsepower

The flap can be depressed more than 45 deg. Above 28 deg. the lift does not increase substantially, but the drag increases considerably from 28 to 45 deg. of flap. The $\alpha\rho$ flap, at the same time that it reduces the gliding speed, increases, therefore, the gliding angle, and also hastens the stopping of the machine when rolling after landing at a given landing-speed. Any device that will increase the drag substantially when desired will serve the purpose. The use of the flap in this case eliminates the necessity of any additional parts.

After obtaining a very low velocity of contact with the ground, the next step to improve safety and efficiency of operation is to stop in the shortest possible space. Of all devices in existence today, by far the most practical for this purpose is the wheel brake. The coefficient of friction of locked wheels in a field is 0.5. This means that the wheels have to be placed sufficiently far forward to overcome the possibility of turning over in case the brakes are locked too hard. Locked-wheel landings have been made successfully with airplanes of the usual types without turning over. Today an ever-increasing number of airplanes are using wheel brakes, and without doubt they will be universally adopted.

The landing run of an airplane can be reduced to less than one-third when using the $\alpha\rho$ flap and no wheel brakes. In this case the per cent of increase of $L_{c\ max}$ was 85 and the wing loading 10 lb. per sq. ft. Brakes

may reduce the run to nearly one-half the remaining distance so that something like one-fifth to one-sixth the original run may be obtained.

Fire Hazard Prevention

Many records of airplane accidents show the cause of a large number of them to be fire. This is indeed an alarming kind of accident but by no means difficult to overcome. Great improvement can be made by observing the following:

(1) All intake manifolds should be leak proof and directly connected to the outside, preferably in a downward direction, necessitating no drain for gasoline condensation

(2) Louvers should be placed to sweep all possible fumes from enclosed gas lines and tanks in case of leakage

(3) Exhaust manifolds should be short and well air-cooled, as recommended by Air Corps tests

(4) Gasoline tanks should project out of the engine in front view and plan view; should be strong and reliable and of all-round careful design

(5) Carefully designed fire walls

These precautions will minimize fire hazards but for the extreme overlooked cases a fire extinguisher should be installed in all aircraft. The type selected should be reliable and automatic or semi-automatic in operation. Air-pressure types may develop leakage or may be found without pressure just when needed.

A simple, light and inexpensive type has been developed and is recommended. The body is a simple cylinder containing the desired quantity of carbon tetrachloride and a pipe can be connected leading to the engine compartment. Small holes at proper locations will drive the liquid to the desired spots when fire may develop. A capsule of compressed carbon dioxide gas is placed on the top of the cylinder and a spring-loaded hammer with a needle is held by a trigger ready to be released. An operating handle can act on the trigger and the releasing valve simultaneously. If a fire is observed the handle is pushed and the liquid driven out at high pressure. When the handle is released the liquid is held in the tank under pressure ready for further use. Normally the liquid is not under pressure and the capsule is perfectly sealed so that no leakage can develop and that operation, when required, is positive.

Portable extinguishers should be used for other possible fires outside of the engine compartment. In case of a crash the extinguisher should be released so as to minimize the chances of fire ensuing.

Visibility and Comfort

Of all things a pilot appreciates in an airplane perhaps the most important one is visibility. In cabin airplanes top visibility has been much neglected. When traffic becomes thick near airports a large range of visibility is indispensable. Imagine an airplane with poor top visibility in climb meeting another with a relatively bad visibility directly underneath in a glide, or a cabin monoplane banking into a turn in which the inner wing and solid top will allow no visibility to the inner side of the turn.

The experimental airplane previously referred to has a pyrolin top allowing unobstructed vision all above the cabin. All pilots flying it have found the visibility to be rather better than in an open cockpit airplane of the

usual type. The windshield in this airplane is lower than in the open types, allowing a better downward angle of vision.

The open versus the closed cockpit is another subject that is still very much discussed. In the future, sending mail pilots out in open cockpit planes in winter as has been done for several years will be considered an unnecessary risk. The pilot protected from outside weather and excess noise will be much more comfortable especially on long flights. He will therefore be able to exercise his faculties with greater accuracy and obviously will be safer. He can never feel too warm since he can always open windows to receive the full stream of air. If a proper heater is installed he can always feel at ease in regard to temperature in winter.

To increase comfort still further, noise should be reduced. This is to a great extent a problem of engine design. The exhaust is easily muffled. The engine parts, however, develop annoying noise. Steps toward minimizing it will undoubtedly follow soon.

Vibration is another phase of comfort and safety that has not been generally solved as yet. Some of the most efficient engine designs are somewhat rough of necessity. The torque fluctuations are large and the mass to which the engine is attached is extremely small. Rubber-isolated engine-mounts are being developed and will finally become universally used unless the engine is of a smooth-running design. A three-blade propeller will greatly reduce vibration in maneuvering due to its steadier gyroscopic action. The propeller is to blame also for a considerable noise especially when the tip speed is high. In the future, geared propellers may be justified to minimize that difficulty, but we believe that enclosed cockpit airplanes will not require them.

THE DISCUSSION

J. C. SLONNEGER[a]:—I understand that at present the landing speed is approximately one-third of the normal flying-speed, and while we could very easily build an airplane for speeds up to 300 or 400 m.p.h., that would mean a take-off and also a landing-speed of perhaps 125 m.p.h. If we could increase that 3-to-1 ratio to 6 or 8 to 1, we would go a long way toward solving the airplane problem, by lowering the landing speed or increasing the flying speed, as we saw fit. What increase in the ratio of landing speed to flying speed has been accomplished by the addition of this flap?

HERACLIO ALFARO:—In the particular case worked out in the paper the landing speed, or rather the stalling speed, would be under 35 m.p.h. while the maximum flying-speed would be above 115 m.p.h.

MR. SLONNEGER:—About 4 to 1 instead of 3 to 1?

MR. ALFARO:—Very few airplanes have a 3-to-1 ratio. Many data on landing speed are incorrect. The landing speed is equal to the square root of the ratio of the wing loading to the maximum lift-coefficient. For a Clark or similar wing-section, the latter is about 0.0035 or at most, in practical designs, 0.0038. This corresponds to a landing speed of 53.5 to 51.3 m.p.h. for a wing loading of 10 lb. per sq. ft.

As you said, the maximum speed could be increased substantially. However, in a racing airplane capable of a speed of 300 m.p.h. and a landing speed of 90 m.p.h. or more, the drag or resistance of the wings is only one-fifth or less of the total resistance and at 350 m.p.h. it may be less than one-sixth. Therefore, you might eliminate the wings entirely, assuming you could, but you could not increase the velocity because the wings represent a small proportion of the drag.

MR. SLONNEGER:—Perhaps the landing speed is also limited by the control of the plane; if we fly at too low a speed, our controls become ineffective and we no longer have control of the airplane. In the early days of aviation that was perhaps the cause of a great many disasters, because the airplanes were designed to fly at 60 m.p.h. and at that speed the control surfaces would, of necessity, have to be rather large. Have you any information on the scheme of increasing the lift of the airplane by reducing the skin friction on the upper

surface by directing a jet of air along it and whether anything further is expected to come of that particular development? The idea looked very good from the wind-tunnel tests, but nothing has really been demonstrated in a practical manner. It partly accomplishes the same thing that you are attempting to secure in a mechanical manner.

MR. ALFARO:—The first part of your question, if I understand it correctly, is lateral control. With the usual type of wing the lateral control becomes very ineffective in most airplanes, today, because the wings are already at the stalling angle, a condition in which an appreciable increase of lift is almost impossible. However, the lift can be increased very slightly by deflecting the aileron downward and increasing, therefore, the camber or wing that needs increase of lift. However, doing so will increase the drag of this wing and the machine as a rule, unless you apply the rudder quickly, tends to turn toward the high-drag wing which cuts down its relative velocity. This condition may become so very bad that almost no response to the controls is secured or, worse still, a reversed action may result.

To avoid that, some time ago in England, the differential type of control was devised, which provides that the ailerons, whenever they act, move down a very small angle, while they move up a relatively large angle. For correcting positions in which the right wing would be low and the left wing high, if the ailerons are applied, the left-wing aileron would go up a much greater angle than the right-hand aileron would go down.

The latter will increase the drag very slightly while the left-hand aileron, by going up so sharply, will increase the drag to some extent and the control in that case operates by cutting down the lift of the high wing rather than by increasing the lift of the low wing. Another very successful means to improve aileron responsiveness at high angles of attack is by placing a slot in the front of the wing which will help to maintain a very flat top of the lift curve or, in other words, a nearly constant lift at high angles of attack.

After reaching the maximum lift, if the angle is increased farther, no substantial drop of lift would follow, which means that the flow on top of the wing is still smooth, due to the action of that slot in the front of

[a] M.S.A.E.—Technical advisor, International Harvester Co., Milwaukee.
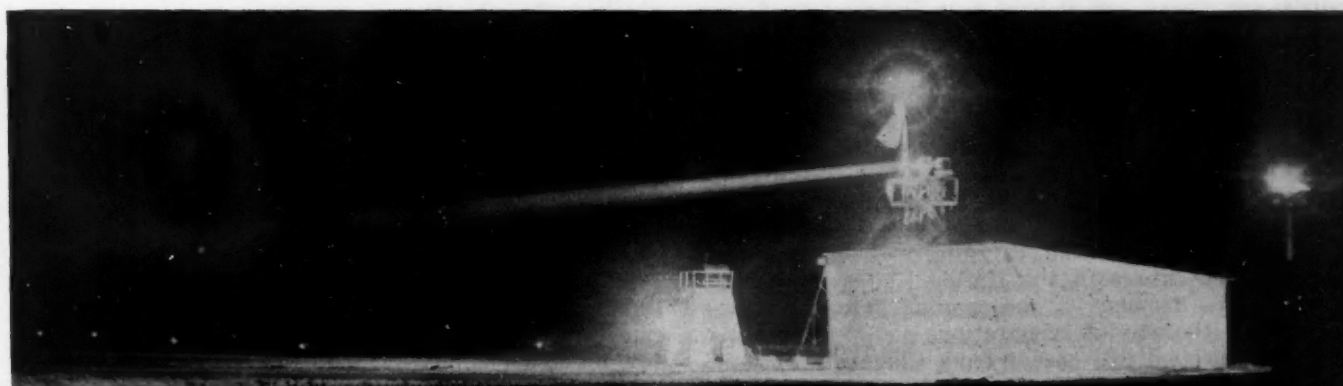
Operation Experience
of the
National Air Transport

By LESTER D. SEYMOUR[1]

METROPOLITAN SECTION PAPER   *Illustrated with* DRAWING AND PHOTOGRAPHS

FROM May 12, 1926, when the National Air Transport began flying over a daylight route 1000 miles long, its operations have grown to 710,552 miles flown in the first third of the present year, of which approximately 45½ per cent represents night flights. The experiences of that organization in assembling equipment and personnel for the first route from Chicago to Dallas and operating it and subsequently the air mail route between New York City and Chicago are covered in the paper. Original equipment on the Chicago-Dallas line was Curtiss Carrier Pigeon airplanes, which were successively replaced by Travel Air, Douglas and Curtiss Falcon machines. On the run between Chicago and New York City, Boeing and Ford airplanes were tried and the decision made to use the former. The reasons for this were lower cost of operation of the smaller single-engine airplanes as compared with the Ford Tri-Motors and the inability to reduce the number of two-section flights.

The policy of the company regarding the acquisition of real estate and buildings is outlined briefly with a short description of its property at the Chicago Municipal Airport. Radio aids to navigation and the weather information system are discussed, the text being supplemented by illustrations of office interiors and equipment.

Based on operation experience, the author discusses day versus night flying and states that unless a definite saving of business time can be effected, as is the case with night flying over routes having a minimum length of approximately 1000 miles, much of the value of the airplane's superior speed is lost. The same is true of daylight flights where the time between the airports and the centers of the terminal cities is approximately the same as the time of flight between the airports. Before air passenger transportation becomes practical, airplanes must carry greater loads and at a considerably reduced unit cost per passenger mile, much more complete weather and communication systems must be available and means must be discovered for landing an anrplane on a fog-enveloped field and preventing the formation of ice on the airplane structure in flight. Manufacturers must also build into their new machines more that has been learned in operation than has been true in the past and the ratio of flying an airplane which is now 90 per cent man and 10 per cent airplane must be reversed.

TO cover adequately the operations experience of National Air Transport during the last year may require that some of the events occurring previously in the history of the company be sketched because last year's activity has been based on these experiences. Our experience is not unlike that of any other company engaged in a pioneering effort where small precedent existed on which to base plans and from which to shape policies. Like most other air transport operations, we have had to proceed more or less by the cut and try method. As is always the case such a procedure has resulted in some misdirected effort but has had the advantage over a period of years of establishing certain fundamentals not hitherto well understood or appreciated. All in all looking back over National Air Trans-

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port's experience, one cannot help but feel that even though the method mentioned has been the only one which could be applied, much has resulted which will serve in years to come as a contribution to this new method of transportation.

On May 12, 1926, National Air Transport began operations between Chicago and Dallas over a route approximately 1000 miles long and six intermediate stops. This route was flown daily during the daylight hours one way in each direction, carrying mail under a contract entered into with the United States Post Office Department. Previous to the opening date, much was required in the way of preparations and very little assistance was available except from Chambers of Commerce and cities along the route because at that time the Department of Commerce Airways Division was not as yet organized.

Equipment and Personnel on Chicago-Dallas Route

National Air Transport had been equipped with 10 Curtiss Carrier Pigeon airplanes and a quantity of spare parts with which to fly the line. The Post Office Department had established a schedule in both directions allowing slightly less than 12 hours between the terminals. All that was left for the operator to do was to go ahead and fly the line twice a day carrying whatever mail was offered. Before the starting date provision had to be made at all of the intermediate stops for hangars to shelter the airplanes, fueling systems, flying and ground personnel, shop equipment, machine and hand tools, and the miscellaneous equipment of every kind required to operate an air line. Our first thought was the proper distribution of airplanes. We assumed that to fly any airplane more than 500 miles in one day was inadvisable in order that opportunity might be had to inspect it carefully and to make whatever minor repairs and adjustments might be necessary. We also decided that approximately 500 miles was as far as it was advisable to ask a pilot to go on one trip, which two decisions to a very great extent dictated the original plan of operation. Kansas City, Mo., approximately in the middle of the line, was chosen as the operating center from which all flying activity would be directed. Here we planned to change both pilots and airplanes. At this point and at the nearby city of St. Joseph, Mo., also on the route, were established our airplane and engine general overhaul shops. With 10 airplanes available and the distances over which any one airplane or pilot would be required to fly in the neighborhood of 500 miles, we decided to assign one airplane to each pilot in accordance with a custom that had been long established in the air mail and other flying services.

To provide for the schedule as set up, four airplanes were stationed at the center of the line in Kansas City, Mo., two at Chicago and two at Dallas. The remaining two were placed, one at Oklahoma City and one at Moline, Ill., these being stations that as nearly as possible equally divided the 500 miles between Kansas City and each terminus of the route. The thought in doing this was that the airplanes at the two intermediate stops would be used for standby purposes and be available for use if for any reason airplanes in flight became disabled between the operations center and either terminus. The exact plan of operations was that each morning one airplane would leave Chicago southbound and one would leave Dallas northbound. When they

reached Kansas City, two of the airplanes stationed there would take up the respective journeys and complete them, being piloted by fresh pilots. In this way in any 24-hour period, barring unusual circumstances, four pilots and four airplanes were used. The plan on the following day was for the airplanes that had been flown on the previous day to return to their home station, being flown always by the same pilots. They would then have 2 days' rest which would give the pilot ample opportunity for relaxation and would permit of a thorough inspection and adjustment of the airplane. During the next period other airplanes stationed as explained, would be operating, those having flown the day previous being considered as in reserve for any emergency that might present itself. No pilots were provided for the airplanes stationed midway between the center and ends of the line so that a total of eight pilots was on the payroll as of the starting date.

Early in the study of our problem we found that if we were to have any success at all in keeping the schedule that had been set up for us, we must pass through intermediate stations as rapidly as possible. Since some of the distances were rather long, being in the neighborhood of 250 miles, which meant that refueling must be accomplished in as little time as possible. To accomplish this, overhead gravity tanks were installed which were filled daily from underground tanks. These overhead fuel tanks held about 200 gal. which was delivered by gravity through a 1½-in. hose to the airplane and actually permitted us to fuel at a rate of about 30 gal. per min. We were thus able to put an airplane through a station in from four to five minutes even including the loading and unloading of mail.

Spare Parts Distributed Along Route

Our spare parts supply was broken up and distributed along the route with the idea in mind of having such parts as we thought might be needed most frequently at points that would permit access to them with the least possible delay in emergencies. For example, at each station one complete Liberty engine ready for installation was available as well as such other parts as wings, control surfaces, propellers, and accessories.

Our personnel, both flying and mechanical, was drawn largely from those who had received training at one time or another in the various Government services. At the smaller intermediate stations two or three men, including the field manager, were employed while at the terminal stations the number was four. At the center of operations in Kansas City, the number was considerably increased because from this point the activities of the line were directed and all of our major overhaul and repair was concentrated there. To test the workability of our operations scheme, regular flying on schedule over the route was begun one week before the starting date carrying such loads as the transfer of equipment and personnel afforded.

Our total operations personnel on May 12, 1926, was in the neighborhood of 51 men. Dividing the mileage flown daily by this figure, we had about one man for each 39 miles of daily flying, or one man for about 20 miles of route length. These figures include the traffic department as well as the general office which housed the bookkeeping department and such other work as engineering and purchasing. The traffic department consisted of a general traffic manager with one division traffic manager stationed at Dallas, Kansas City and

Chicago. The bookkeeping or auditing department consisted of one auditor with an assistant. One engineer and one purchasing agent were employed. All field operations of the company were under the direct supervision of the manager of operations who, however, was stationed at Kansas City. Pilots of the company were responsible to the manager of operations and the various field managers were in charge of all mechanical and service work carried on at their stations. These various departments were responsible to a general manager located in the general offices at Chicago.

Early Communication and Weather Systems

The communications system used was Western Union Telegraph and the method of dispatching airplanes and reporting weather was of the simplest nature. At each station where a plane stopped, a weather report had been procured from the next field to which it was to go, and this information was given to the pilot upon arrival. The operations office kept track of the position of airplanes on the route by a system requiring the report of a departure from any station to the next station along the route as well as to Kansas City at the same time. Our weather system consisted of Government weather observers stationed at Moline, Ill.; Kansas City, Mo.; and Oklahoma City; in addition to the Army weather station at Dallas, and the central district office of the Weather Bureau at Chicago. Information regarding the weather was transmitted by the Weather Bureau from these stations twice daily to strategic points along the route and inquiries from our own personnel were directed to these offices at such times as seemed necessary. This in effect was the set-up of our operation when beginning flying activity on May 12, 1926.

Operations were carried on during 1926 according to the scheme detailed above with modifications from time to time. It soon became evident, however, that the 1000-lb. payload capacity of the Curtiss Carrier Pigeons was in excess of the requirements of the line. With an idea of finding out the passenger carrying possibilities of the route, eight Travel Air monoplanes, equipped to carry both passengers and mail, were purchased and put into service in August, 1927. These airplanes, which were equipped with Wright Whirlwind engines, were designed to carry 750 lb. of payload, divided between passengers and mail. Only eight were used because the Carrier Pigeons would be still available for emergency purposes and experience had taught us that very little use was required of the airplanes which had been stationed at intermediate points along the route for reserve purposes.

Our experience in the matter of passenger carrying was extremely interesting. We found that even at the comparatively high rate of 10 cents per mile, a considerable volume of passenger traffic might be secured and that such traffic was appreciably heavier over those portions of the route that were not so well served by train. This was our first practical proof that transportation in the air was directly related to rail transportation on the ground. We have since learned how very close this relation is and just how great an effect rail competition may have under certain circumstances.

New York City-Chicago Operation Begun

On Sept. 1, 1927, we began operations on a contract that we had secured from the Post Office Department to carry the mail between New York City and Chicago

on two schedules in each direction daily, one during the daylight hours and one at night. At the same time air express service over all our lines was inaugurated under a contract with the American Railway Express Co. At the time of taking over this new operation, the operations manager's office was moved from Kansas City to Chicago, and many of the Post Office Department employes who had previously been operating the New York City-Chicago line were engaged. All of the pilots and most of the field force came from the postal service. The company also purchased from the Department some of the then surplus Douglas mail planes with which to operate the new route. The traffic department was extended to include a division traffic manager in New York City and the route was operated from Cleveland, which divided the distance between Chicago and New York City. At this time the set-up of operating organization was changed only in that the two routes were operated as two separate divisions, each with a division superintendent responsible to the manager of operations now stationed in Chicago. For this service, requiring about 3000 miles of flying daily between New York City and Chicago, some 18 Douglas airplanes were put into service and 12 pilots were employed.

Airplanes were operated in much the same manner as had been the practice on the Dallas line and in the Post Office service. About twice as many airplanes were concentrated at Cleveland as at Chicago and New York City, and one was placed at Bellefonte, Pa., and one at Bryan, Ohio, as reserve equipment. Engines were again distributed along the line as were other spare parts. At this time the total operating personnel of the company was in the neighborhood of 162, or about one man for each 30 miles of daily flying. At Cleveland, the eastern division operating center, the overhaul and repair depot for airplanes operating on that division was established whose superintendent, as in the case of the southern division, was directly responsible to the manager of operations.

The communications system employed at the beginning of operations was through the Government radio stations situated at Chicago, Bryan, Cleveland, Bellefonte, and New York City. By this time the Department of Commerce had begun operations under the Air Commerce Act of 1926 which permitted the radio stations mentioned to be operated in the interest of the contractor carrying the mail over the route. Passengers were carried in emergency cases when mail loads and weather would permit.

Night Flying Between Chicago and Dallas

In February, 1928, it became apparent that the Chicago-Dallas service could not be of the greatest benefit to business unless it was operated at night and so the schedule was advanced approximately 12 hours over this route. The airplanes left each terminus at nightfall rather than in the morning. For this service, Douglas airplanes taken from the eastern division were worked in with the Carrier Pigeons, finally replacing them entirely and in turn were replaced by Curtiss Falcons equipped with Liberty engines and capable of considerably greater speed than the Travel Airs that had already proved themselves not so well suited for the line as the Douglases in the matter of speed. The great number of intermediate stops and adverse prevailing head winds had no little effect on the situation already aggravated by a fast schedule.

TABLE 1—OPERATING STATISTICS OF THE NATIONAL AIR TRANS-
PORT FROM MAY 12, 1926, TO APRIL 30, 1929

Period	Mail Carried, Lb.	Miles Flown[e]	Airplanes in Service	Personnel Employed
May 12–June 30, 1926.....	15,688	*153,856*	12	51
July 1–Dec. 31, 1926......	48,871	*394,216*	12	59 [c]
Total for 1926.........	64,559	*548,072*		
Jan. 1–June 30, 1927......	51,522	*378,193*	16	59 [c]
July 1–Dec. 31, 1927......	231,362[a]	*537,736* **177,777**	35	185
Totals for 1927.... {		*915,929* **177,777**		
	282,884	1,093,706		
Jan. 1–June 30, 1928......	352,609	*554,549* **431,735**	36	188
July 1–Dec. 31, 1928......	779,352	*599,949* **579,436**	36	246
Totals for 1928.... {		*1,154,498* **1,011,171**		
	1,131,961	2,165,669		
Jan. 1–April 30, 1929......	574,287[b]	*388,010* **322,542**	46	285
Total, 4 months 1929....	574,287	710,552		

[e] Figures in italics indicate miles flown in the daytime and bold-
face figures indicate miles flown at night.

[a] Figures are for 6 months of Chicago-Dallas line and 4 months
of Chicago-New York City line.

[b] All mail loads.

[c] Does not include general overhaul shop.

Since cities north of Kansas City would be afforded
little or no service at all with a night schedule, an addi-
tional daytime schedule was put on between Kansas
City and Chicago. On this schedule airplanes left Chi-
cago southbound for Kansas City in the morning and
Kansas City for Chicago shortly after noon. The
Travel Airs that had been used between Chicago and
Dallas were now placed in service on the day line be-
tween Chicago and Kansas City. Excluding the Carrier
Pigeons, which were then out of service, we had 30 air-
planes in commission and were flying about 6000 miles
daily or one airplane for each 200 miles flown.

Changes Resulting from Increased Operations

By the summer of 1928, we found that operations
could be materially benefited and considerable economy
effected by the concentration of our overhaul and repair
facilities at a central point. Chicago was selected and
the overhaul shops at Kansas City and Cleveland were
consolidated and moved.

At this time the daily mileage had increased to a
point where assigning a particular airplane to each
pilot was no longer possible. Also if airplanes were to
receive maximum use and return maximum benefits,
they must be flown a continuous trip length of more
than 500 miles. With this thought in mind, the opera-
tions plan was changed so that the greatest concentra-
tion of airplanes was at Chicago with only standby or
reserve planes at Kansas City, Cleveland, New York
City, and Dallas. Under this plan an airplane leaving
Chicago was expected to fly to Dallas or New York City
and return as the case might be. All major repairs and
overhauls were to be at Chicago, only service repairs
being made at any other station. This reduced the
spare equipment required along the line as well as the
personnel at the various stations. Under this plan only
sufficient men to move the airplanes about and make
minor adjustments were required at points other than
Chicago. Under this system, however, no change was

made in the amount of flying required of pilots, it be-
ing planned that on the eastern division in any one day
a pilot's mileage should be only that between New York
City and Cleveland or between Cleveland and Chicago.

In August, 1928, the 5-cent air mail rate went into
effect resulting almost immediately in a 100-per cent
increase in loads over all lines. Immediately the neces-
sity for additional airplanes of greater capacity became
apparent and it was found necessary most days of the
week to send two sections on many of the schedules over
the eastern division rather than one. To find out how
to take care of this situation best two experiments were
made; one by the trial of Boeing airplanes capable of
carrying 1600 lb. and the other by the use of Ford Tri-
Motors capable of carrying 2500 lb. of payload. These
experiments extending up almost to the present have
resulted in the recent acquisition of a fleet of six Boe-
ing airplanes capable of a speed approximating that of
the Douglas equipment but able to carry about 1600 lb.
as against 1000 lb. The use of the Ford airplanes for
mail carrying over this route has been discontinued
for the present as we found that the increased cost of
their operation over the smaller single-engine airplanes
was not yet warranted in view of the mail loads avail-
able and the ability of the smaller 1600-lb. airplanes to
reduce the number of second sections referred to above.

With the second sections that are now necessary we
are averaging approximately 7000 miles of daily flying
and the total operating personnel is 285, the number of
miles of flying per employe per day being now about 21.
This does not compare unfavorably with the figure at
the beginning of our first daylight operations when the
fact that nearly half of our total mileage is now flown
at night is remembered. When the flying of a route is
all done in the daytime, only one shift is required,
whereas when operations are changed to night flying
and the operation becomes a 24-hour or three shifts per
day effort, the number of men required increases ac-
cordingly unless steps are taken to operate the line more
efficiently or the number of flights daily over any par-
ticular line is increased accordingly. In addition our
first figures did not include personnel for general air-
plane and engine overhaul.

From the experiences recounted above, statistical
records have considerable to interest the air transport
engineer. With this in mind Table 1 has been prepared
showing the increase in mail poundage from time to
time, personnel employed, the number of airplanes in
use, and the division of flying into night and day op-
erations. The present operating organization can be
seen at a glance from Fig. 1.

Policy Regarding Real Estate and Buildings

Like most other air transport companies, we have
shaped our policy regarding the ownership of buildings
and real estate to meet the various situations as they
arose. At no points save Chicago, Cleveland and Belle-
fonte, Pa., have we invested in the construction of
hangars or other buildings. At the last named housing
a spare airplane was necessary because of the peculiar
weather conditions and locality. As no suitable build-
ings were available, this necessitated the construction
of one small hangar. At Cleveland the company has
erected a modern brick and steel hangar 100 ft. x 120
ft. on the City Airport. At Chicago, our central oper-
ating point, we have erected and acquired on the Muni-
cipal Airport hangars and shops with a floor area in

excess of 45,000 sq. ft. as well as a two-story brick office building with a floor space of approximately 5000 sq. ft. housing the general offices. One hangar of this group with a clear span of 160 ft. is believed to be the largest clear span hangar yet built in this Country.

The Chicago overhaul and repair depot employing about 100 men is complete in every detail and equipped with the most modern machine-tools for the manufacture of parts and the general overhaul and repair of aircraft and engines. At present this shop turns out one completely overhauled engine every 4 days and one completely overhauled airplane every 10 days. The heating system of the entire group of buildings is of the central type and consists of low-pressure steam boilers distributing heat in the various buildings by blower-type unit-heaters suspended overhead. This system of heating gives excellent distribution, places the heat where most needed and has been found considerably more economical and effective than other types of heating previously used.

Aids to Navigation

Since the Air Commerce Act of 1926 has been in effect, the improvement of many of the aids to navigation by the Department of Commerce has added greatly to the efficiency with which the service has been operated. These aids to navigation include the establishment of a much more comprehensive weather system, the improvement of route lighting, the enlargement and relocation of intermediate fields and the improvement and establishment of additional radio aids to navigation. The help that has been afforded by the lighting of many portions of our routes and the improvement of the lighting systems previously installed by the Government and by ourselves would be difficult to overestimate. The lighting of intermediate fields at 30-mile intervals along the routes, the addition of course lights on revolving beacon towers, the improvement in boundary lighting of various fields and the substitution of more

powerful acetylene range lights for the original acetylene blinkers have gone a long way toward making service more reliable and safe for our pilots who fly at night.

The weather system that has been placed in operation by the Weather Bureau and the Department of Commerce along our lines, while as yet in the development stage, has added materially to our ability to cope with adverse weather conditions. From New York City to Chicago the Department of Commerce, in addition to the point-to-point radio network, already established when the route was taken over, has added a land wire teletype system connecting all stations, over which is disseminated hourly weather information and forecasts collected from a number of stations along the line and on each side of it. The interior of a dispatching office equipped with the teletype system is illustrated in Fig. 2 and Fig. 3 shows weather observations being taken at the Chicago airport.

In the matter of radio, we believe that the work now begun by the Department of Commerce, in which we have been privileged to cooperate, will one day result in an increased performance under bad weather conditions which will be unprecedented in flying experience. Work already accomplished includes the establishment between New York City and Chicago of a line of radio beacons and voice transmitters that broadcast weather forecasts and conditions regularly at hourly periods. Fig. 4 shows one of the radio stations operated by the Department of Commerce on the Chicago-New York City route. Our airplanes flying over this route are equipped with radio receivers, installed as shown in Fig. 5, and follow the beacon beam between all stations and are afforded great assistance by these voice forecasts.

As an example of the necessity of these radio aids to navigation, especially over country such as that existing through the Allegheny Mountains between Cleveland and New York City, an experience that is becoming
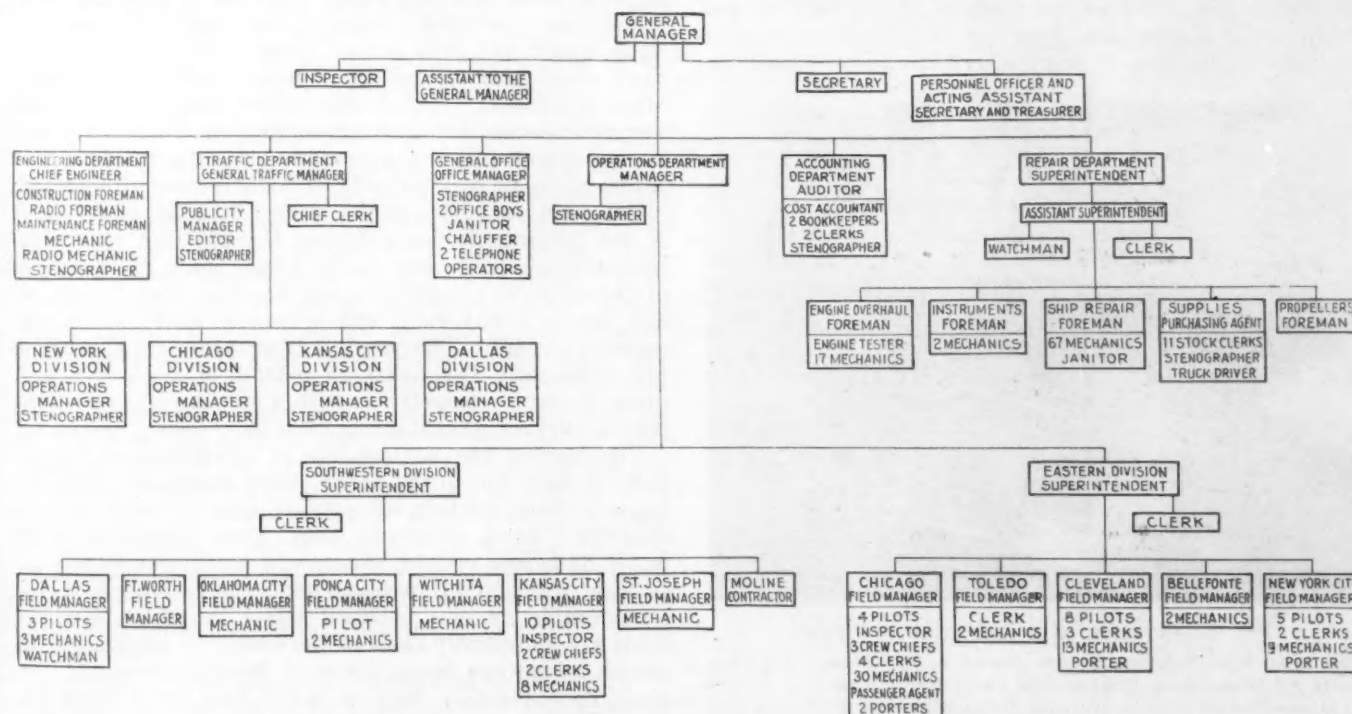

FIG. 1—ORGANIZATION CHART OF THE NATIONAL AIR TRANSPORT

more frequent daily, may be cited. One of our pilots recently flew from Bellefonte, Pa., to Hadley Field, our New York City terminus, without seeing anything but his instrument board the entire distance until he came out at Hadley Field under a ceiling of 800 ft., the existence of which had been announced to him enroute by radio. He left Bellefonte flying completely blind and continued to do so throughout the entire distance, keeping to his course by the radio beam and being informed periodically that Hadley Field was clear with an 800-ft. ceiling along with the weather forecast enroute. He was also told that certain fields south of the route, to which he might go should Hadley have shut down before he arrived, were clear. Such information is vital and in this particular instance, as well as others that might be cited, the radio beacon and the voice transmission of radio weather information have meant the difference between the successful completion of a trip or a failure that would probably have been recorded had not these marvelous aids to air navigation been available.

In conjunction with the Department of Commerce, we are working in an effort to secure a transmitter light enough and small enough to be mounted in the single-engine mail airplanes. This will make our radio a two-way communication system instead of ground to airplane only as now. Indications are that our efforts in this direction will shortly bear fruit and we hope that by winter, when the worst weather is encountered, all of our airplanes flying over the mountains may be in constant contact by two-way radio communication with ground stations for the entire length of the route.

Day versus Night Flying

In addition to the statistical information given above, our operations so far seem to indicate certain conclusions that for the time being may perhaps be taken as fundamentals on which to base expansion and enlarged operations. To set some of them down for the consideration of those who are studying the subject may prove interesting. First of all, air transportation is rapidly reaching a point where it can no longer de-
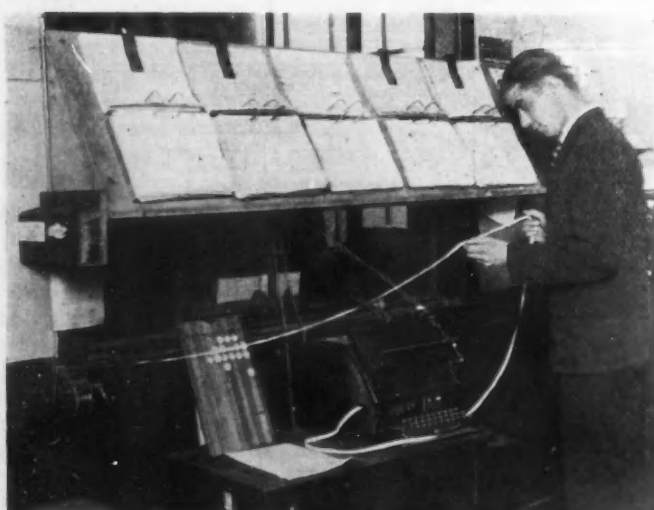
FIG. 2—INTERIOR OF A DISPATCHING OFFICE

The Land-Wire Teletype System Shown in the Foreground Connects All Dispatching Stations and Supplements a Radio Network in Disseminating Hourly Weather Information and Forecasts Collected from Stations along and to Each Side of This Line

pend upon civic pride and novelty for support but must offer a definite and superior service over other forms of transportation if it is to succeed. Frequency of service, the length of any route in question, the competition of other established forms of transportation and the dependability of the service offered are essentials that cannot be neglected if any air transport line is to
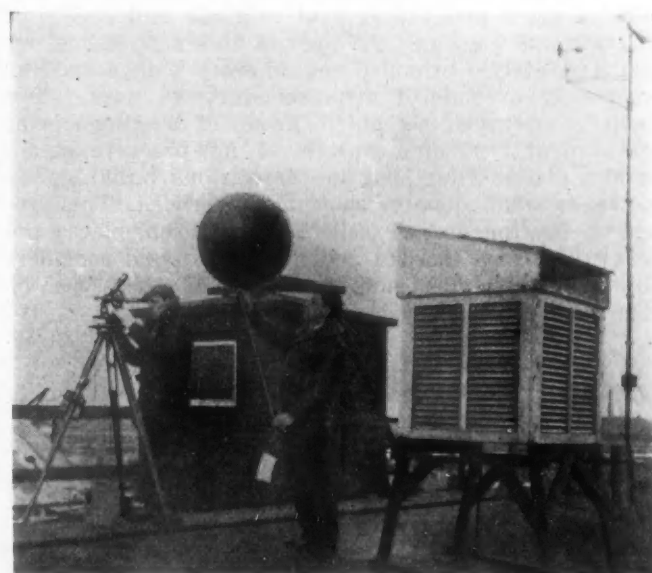

FIG. 3—TAKING WEATHER OBSERVATIONS AT THE CHICAGO AIRPORT

Forecasts and Information about Weather Conditions Based on These Observations Are Broadcast Hourly to the Pilots on the New York City-Chicago Air Mail Route by Voice Transmitters and Transmitted to Dispatching Stations by Radio and by Wire

succeed. In this same category must be considered the particular time of day that any given route is flown. If two cities are separated only by a distance over which train schedules provide overnight mail service, little advantage will accrue from establishing an air mail route because no appreciable saving in business time is effected. If, on the other hand, the distance separating two cities is approximately twice as great as that which can be traversed by existing trains in the night, air mail service to fly at night between these two cities meets a very definite need. On the other hand if the distance is flown during the daylight hours, no business time has been saved, hence much of the value of the airplane's superior speed has been lost. As a result we feel that more and more air mail routes will operate at night. Expanding this theory, if the cities are sufficiently far apart to permit of both day and night flying in competition with a continuous train trip then a further advantage is offered.

Considering the advisability of air transport operations in addition to the above, short routes in some instances afford certain advantages even if flown in the daytime. Here, however, they must either be over water or across country where the circuitous routes of surface transportation make competitive transport inconsiderable or else between cities in which landing fields are sufficiently close to the center of population to permit advantage being taken of the time saved in the air. To explain, I have in mind two cities approximately 240 miles apart between the centers of which
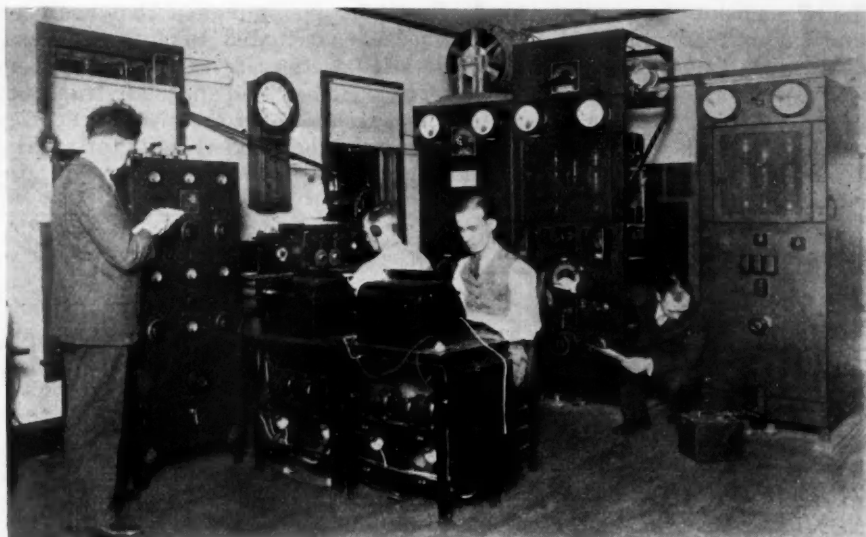
FIG. 4—INTERIOR OF A RADIO STATION OPERATED BY THE DEPARTMENT OF COM-
MERCE ON THE NATIONAL AIR TRANSPORT ROUTE BETWEEN NEW YORK CITY AND
CHICAGO

eration costs increase when night flying is involved and with airplanes and engines that have been available so far, considerable experience is required before the best results can be secured from them. For example, with the refinements that have been made, our present Liberty engines are flying with greater freedom from mechanical trouble than ever before although they are now run 250 hours between overhauls as compared with 50 hours between overhauls six or seven years ago. In fact, records are now being made with these engines which a few years ago would have been unbeliev-able. We frequently fly as much as 350,000 miles with Liberty engines between mechanical forced-landings. By the same token airplanes have had to be in use for a number of years and developed through service tests and refinement before their greatest value could be realized. As an example of this may be cited the Douglas mail airplane that in the main essentials is now very similar to what it was when it first came into service about five years ago. Some details have been so changed, refined and improved that now we can operate one of these air-planes safely 1000 miles out of its home station and back daily over long periods with nothing but service repairs and adjustments enroute when, as explained in the early part of this paper, 500 miles was considered the limit less than three years ago. As time goes on
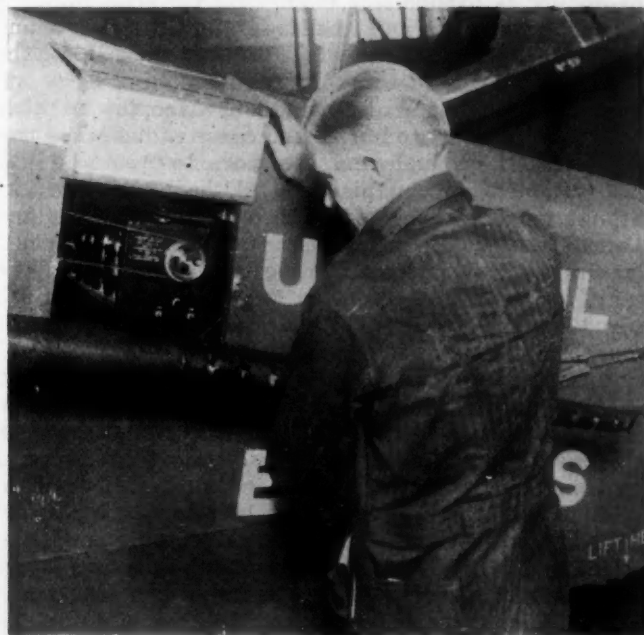
train service is afforded in about 4½ hours. The dis-tance between the airports used by these two cities may be flown in about 2 hours, but since almost 1 hour is re-quired to get to and from the airport of either terminal, airplane service between the centers of the two cities really affords little advantage.

These comparisons are, of course, made on the basis of present airplane speeds which perhaps may be as-sumed to be slightly more than twice the speed of our fastest trains. When airplanes have increased their speeds, as we confidently expect they will, the relation between distances and competitive surface transporta-tion will change proportionately. If we can judge the future by the past, airplane speeds will undoubtedly have doubled within the next three years, which will completely change our whole outlook on the advisability of establishing air routes either for passengers or in-animate cargo between any two specific points.

Passenger Transportation Outlook

Although we have only flown passengers experi-mentally, we believe that before transportation in the air of passengers over any except very long or very short routes becomes practical, several things must hap-pen. First airplanes must carry greater loads and at considerably less unit cost per passenger mile. A very much more complete weather system and radio com-munication system must be available. Before the ulti-mate is reached in air transportation for either pas-sengers or cargo some means must be discovered for taking care of a situation such as the terminal landing-field being enveloped in fog and for combatting the for-mation of ice on the airplane structure in the air. Ra-dio in one form or another may soon solve the problem of flying through almost any sort of weather, but no satisfactory method has as yet been proposed to enable an airplane to land when the pilot cannot see the ground nor has one been evolved to eliminate the danger of ice formation.

Operation costs per mile are reduced in proportion to the number of schedules that can be flown over any par-ticular route up to a certain as yet indefinite point. Op-

FIG. 5—LOCATION OF RADIO RECEIVER ON AN AIRPLANE FLY-
ING BETWEEN CHICAGO AND NEW YORK CITY

These Receivers Enable the Pilot To Follow the Radio-Beacon
Beams and Thus Maintain His Course at Night or When the
Visibility Is Poor and Also Provide Him with Hourly Reports on
Weather Conditions Enroute, at His Destination and at Possible
Landing Points

perhaps this service experience may not be of such importance but this will not be, however, until manufacturers are able to build into their new models more that has been learned in operation than has been true in the past.

All that has been set down regarding our history and experience in air transport is of interest merely to assist future operations to continue from that point already attained. However, one statement that has been made by a man who has contributed much to the development of transportation in the United States sums up the situation very well. He has said that "air transport will not come into its own and be of the ultimate service of which it is capable until the ratio of flying of an airplane which is now 90 per cent man and 10 per cent airplane is reversed."

Possible Improvement of Present-Day Aircraft

(Concluded from p. 216)

the wing. Therefore, in that slot flow, the aileron secures fairly good action and almost any type of aileron was very responsive.

Another type of control, which I described in the paper, is the spoiler which is located so that when the control is operated, the spoiler sticks out of the high wing, while in the low wing it remains in place. The high wing has the flow disturbed, the lift is broken down by that disturbance of flow and that wing droops. At the same time, the flow disturbance increases the drag, the high wing goes backward and the low wing goes forward and favors the rolling motion of the ship toward a satisfactory rolling control. The spoiler, however, is very ineffective at low angles of attack or at high speed; therefore, it cannot be used by itself. It is satisfactory for low speed, even above angles of maximum relief. The flow above the wing is very fast at the region where the spoiler is located.

Your second question, I believe, referred to the boundary-layer removal on the wings or removal of skin friction, if we can call it that, on top of the wing so as not to retard the flow and also not to allow the flow to stick to the top and start to burble and cause eddies when the wing is at a high angle and, therefore, to break the lift. One system to obtain this involves the blowing of air through small openings from the top of the wing; another is the suction of air from outside of the wing. The first experiments that I know of were made in Germany, but no record, however, was kept of the air required by the device. The increase of lift was enormous, but probably was obtained at a great cost of blowing air. However, some other tests have been made by the National Advisory Committee for Aeronautics in this Country, with conservative figures of horsepower investment into that device. These show that the type absorbing air from the outside is more efficient than the one blowing air out. Both achieve about the same result but with a greater efficiency for the one of the suction type. By absorbing the air the immediate layer that travels with the wing was removed and therefore, the flow became smooth and greater lift was obtained. I believe we can obtain more than that with the previously described type of flap with no additional power-

plant. I do not think that it would be practical, because it requires addition of weight and power for either blowing or absorbing air.

MR. SLONNEGER:—That scheme contemplated using the energy of exhaust gases to supply the necessary air and the energy in the exhaust gases was calculated to be sufficient to supply the air required.

MR. ALFARO:—That is right and the tests were made that way. Probably when you need that air the most, however, is just when your engine is stopped and you have no gas from the exhaust.

MR. SLONNEGER:—That is very true, of course, in an emergency landing.

MR. ALFARO:—The idea is very interesting, and I am only speaking about preliminary experiments. However, I will say that the increased weight of accessory equipment was not very large although increase in the weight of the wings themselves would become very substantial.

CHAIRMAN C. L. COLE[10]:—What has been done to prevent the formation of ice on wings?

MR. ALFARO:—Very little has been done. Attempts have been made to cover the wings with paraffin and other such compositions, but they have not given satisfactory results, according to the information I have had. The Bremen, when it crossed the Atlantic, was reported as being successful due to a heavy coating of paraffin on the wings. Later I learned that her success was rather her good fortune in not running into any sleet forming regions, because sleet forms even with paraffin and in some cases such formation was quicker. At least, that was the experience of air mail lines running through Cleveland. The little drops of water attach themselves quicker to a coat of oil and apparently form ice more rapidly with the oil than without. Ice can form over a very wide range of temperatures. At the beginning the temperature was thought to be very close to freezing; later we learned that ice can also form at other temperatures, depending on the quantity of moisture.

Heating of the wings with exhaust gases may be a solution, especially when metal wings are used. I believe this should be done by locating those heating pipes near the leading edge, since the accumulation of ice is more abundant near the leading edge than at other places.

[10] M.S.A.E.—Vice-president and engineer, Williams, Cole & Wolff, Inc., Milwaukee.

Airplane Stability

By Lieut.-Commander L. B. Richardson[1], U. S. N.

IF AN AIRPLANE is following a straight path and is diverted from it as by flying into an up-current of air, the author states that it may act in any one of four ways. First, it may return to the original course without oscillation, thus showing the most complete stability. Second, it may oscillate with decreasing amplitude until it returns after a few heavily damped oscillations to the original path, thus showing stability of a lesser degree. Third, it may make a series of oscillations of gradually increasing amplitude, thus showing static stability but lack of dynamic stability. Fourth, it may diverge steadily from the original path, thus showing static instability and into which condition no question of dynamic stability enters. These four conditions indicate that an airplane is statically stable longitudinally when it tends to return toward the condition of steady flight, and that it is dynamically stable when the oscillations of the statically stable machine are damped so that there is actual return to the original condition.

The subdivisions of the subject are the statical and dynamical longitudinal stabilities, lateral and directional stability, autorotation and spinning, and special consideration of the flat spin.

To avoid flat-spinning tendencies, the airplane designer should give biplanes ample stagger and gap. Factors tending to damp yaw, such as long fuselages and generous fin-areas, should be emphasized as much as possible without making the airplane clumsy from excessive directional stability. Finally, the weights in the fuselage should be concentrated as much as possible along a small portion of the length of the airplane, and weights located far back toward the tail should be avoided particularly.

In the discussion, questions and answers include the subjects of the most-forward position for the center of gravity in which the performance of the airplane is still satisfactory, the effect that a retractable landing-gear would have upon the spinning tendency of a low-wing monoplane, and the advantages which can be gained by locating the engine in some specified position.

STABILITY is considered the most difficult subject in the theory of airplane design, because of the obstacles it presents to mathematical treatment and the difficulty of obtaining reliable information on the flying qualities of airplanes. However, a vast amount of experimental work in the wind-tunnel and by means of flight tests has been done, as well as mathematical work, and it is now possible to predict with considerable accuracy the stability characteristics of a given design. Stability in mechanics is defined as that property of a body which causes it to return to an original condition of equilibrium or steady motion when disturbed therefrom, and this paper presents the fundamental theories, based upon the excellent works of Edward P. Warner[2] and Charles N. Monteith[3]. Of the accompanying illustrations, Figs. 1 and 4 are reproduced from Mr. Warner's book and the other ten from Mr. Monteith's book, through the courtesy of the respective publishers and by permission of the Chief of the Air Corps of the Army and of Col. C. C. Carter, U. S. A.

Kinds of Stability

The foregoing definition is incomplete in its application to the airplane, because several sorts of stability are recognized. If an airplane is following a straight path and is diverted from it, as by flying into an up-current of air, it may act in any one of four ways: It may return to the original course without oscillation, thus evidencing the most complete stability; it may oscillate with decreasing amplitude until it returns, after a few heavily damped oscillations, to the original path, thus showing stability of a lesser degree; it may make a series of oscillations of gradually increasing amplitude, thus demonstrating static stability but lack of dynamic stability; or it may diverge steadily from its original path, thus exhibiting static instability, into which condition no question of dynamic stability enters. Hence an airplane is statically stable longitudinally when it tends to return toward the condition of steady flight, and is dynamically stable when the oscillations of the statically stable machine are damped so that there is actual return to the original condition.

If the airplane is flying with wings level and is suddenly banked to one side, it may return to an even keel or it may continue to roll. It exhibits lateral stability in the former case, or stability in roll. If it is flying in a given direction and is thrown off the straight course, it may return to it or may continue to turn until it loses speed and falls. Directional stability, or stability in yaw, sets up the forces which restore it to the straight course.

Statical Longitudinal Stability

We shall consider first the requirements for statical longitudinal stability, with which proper balance is closely coordinated; that is, freedom from pronounced nose or tail heaviness at the most usual speeds of the airplane. In general, for the airplane to be statically stable, it is necessary that the moments of all forces about its center of gravity shall resist the change in its angle of attack. If the angle of attack is increased, the resultant moment must be negative or in the direction to decrease the angle, this being termed the diving moment. If the angle is decreased, the resultant mo-
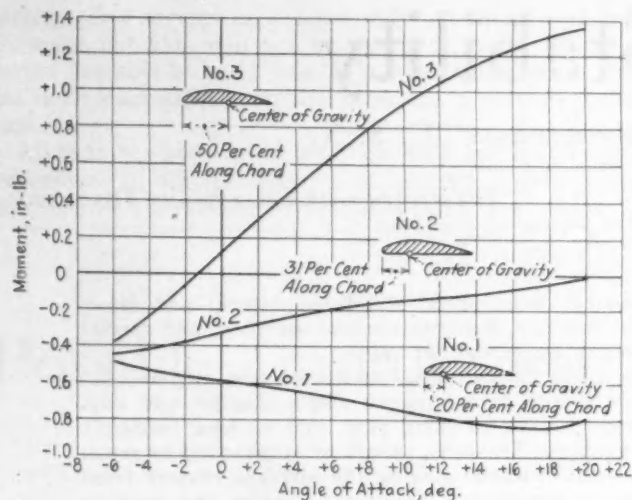
FIG. 1—CURVES SHOWING THE EFFECT OF THE POSITION OF THE CENTER OF GRAVITY ALONG THE CHORD OF THE AIRFOIL MOMENTS ABOUT THE CENTER OF GRAVITY
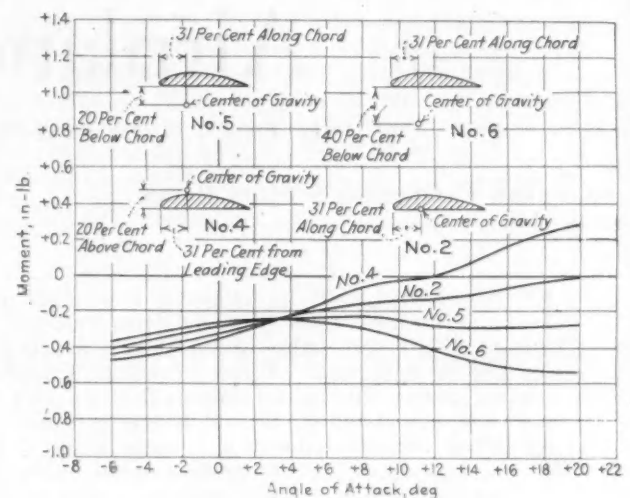

FIG. 2—CURVES SHOWING THE EFFECT OF THE POSITION OF THE CENTER OF GRAVITY ABOVE OR BELOW THE CHORD ON MOMENTS ABOUT THE CENTER OF GRAVITY

ment, termed the stalling moment, must be positive and tend to increase the angle. The rate of change in the moment about the center of gravity per unit change in angle should be as nearly constant as possible, and always should be of negative value. The curve of resultant moments about the center of gravity plotted against angle of attack should have a negative slope throughout and, when plotted against air speed, it should be a straight line with negative slope. These conditions must be satisfied for all stabilizer settings and for all elevator an-

FIG. 3—COMBINATION OF WING AND TAIL-MOMENT CURVES AND A COMPARISON WITH THE MOMENT CURVE OF THE VE-7 AIRPLANE MODEL

unstable and balances at the angle of maximum lift. If the center of gravity is moved farther back along the chord, the system becomes unstable, the moments due to increase or decrease in angle of attack tending toward still further increase or decrease, respectively.

It is thus seen that the most important influence on static stability is the longitudinal position of the center of gravity of the airplane. The vertical position of the center of gravity with relation to the chord is much less significant, though a low position tends to increase

gles. Fig. 1 presents curves that show the effect of the position of the center of gravity along the chord of the airfoil moments about the center of gravity.

The two most important influences on the statical longitudinal stability of the airplane are the pitching moment, caused by the tail plane; and the location of the center of gravity of the airplane, both horizontally and vertically, with relation to the wing chord. When the center of gravity is located well ahead of the maximum forward position of the center of pressure of the wing system, the system is stable. There is an increase in diving moment when the angle of attack increases, and a decrease when the angle decreases. The diving moment is always present, however, and for this reason the wings by themselves will not balance but must be balanced by the air load on the tail. If the center of gravity were located at any one position of the center of pressure, the system would balance only at the angle of attack corresponding to that position. With the center of gravity exactly at the maximum forward position of the center of pressure, the system is slightly

the longitudinal stability of the system at high angles of attack and it is advisable to locate the center of gravity at least 20 per cent of the chord below the mean chord. Fig. 2 shows the effect of the position of the center of gravity above or below the chord on moments about the center of gravity.

The tail plane, that is, the stabilizer and the elevators, constitutes the other important influence on statical longitudinal stability. It is the most powerful factor in dynamic stability, as will be discussed later. The moment of the tail plane about the center of gravity of the complete airplane tends at all times toward static stability; that is, it always exerts a restoring moment, its action being similar to that of a weather-vane.

There are four variables in the tail-surface moment: area, distance behind the center of gravity, airfoil section of the tail, and the plan form of the tail as it affects aspect ratio. Each of the first two is practically self-explanatory as to its effect on the restoring moment due to the tail.

The selection of airfoils for use as tail surfaces is governed by the desire for sections having the greatest possible rate of increase of lift with tail angle, the lowest possible drag, and sufficient thickness to allow strong tail structures without excessive external bracing. The plan form of the tail should give the maximum practicable aspect ratio, thus increasing the tail efficiency. It has been found that an increase in aspect ratio from 2 to 3 in a tail surface has the same effect as a 15-per cent increase in tail area. Fig. 3 shows a combination of wing and tail-moment curves and a comparison with the moment curve of the VE-7 airplane model. Fig. 4 illustrates the building-up of pitching moment by summation.

Assuming a certain position of the center of gravity with respect to the wing chord, say at 31 per cent of the chord from the leading edge, a condition of instability of the wings alone exists; all moments for the wing are diving moments, and the curve of moments has a positive slope. The tail surfaces have a moment curve that has a strong negative slope, since all moments due to the tail are restoring; the combination of
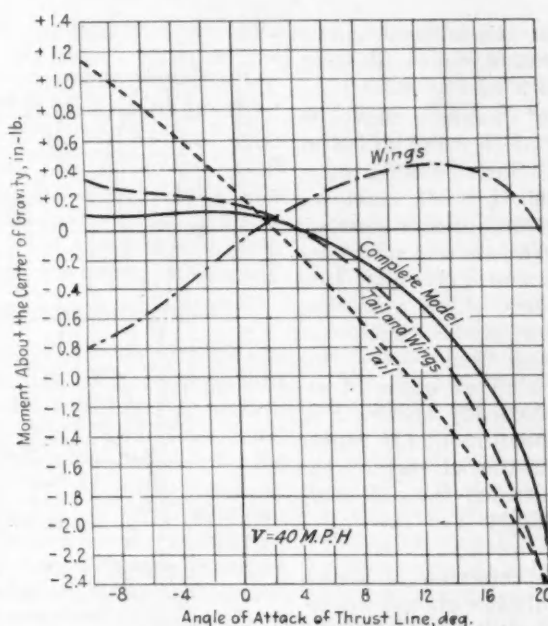
FIG. 4—BUILDING UP OF PITCHING-MOMENT CURVE BY SUMMATION

the two gives the moment curve for the airplane, the resultant of the wing and tail forces acting to make the airplane statically stable.

If the center of gravity is located too far back along the chord, the airplane will be stable only above certain angles of attack, say 6 or 8 deg., and will be unstable at all smaller angles. If the stabilizer angle is changed to balance the airplane at some very low angle of attack corresponding to high speed, the airplane will be found to balance also at some larger angle, say 12 or 15 deg. above the lower balancing-point. This may lead to the condition known as catastrophic instability. The airplane possessing this defect has a moment curve which crosses the axis two or three times; that is, there are two or three angles of attack at which the moment about the center of gravity is zero. If one of these angles is below that of zero lift, the airplane, upon reaching it, will go into a dive and continue until it is flying inverted, from which position recovery is impossible. If one balancing angle is above that of maximum lift the airplane, upon being disturbed, will jump to that angle, lose flying speed and fall. Fig. 5

FIG. 6—MOMENT CURVE ILLUSTRATING CATASTROPHIC INSTABILITY

FIG. 5—COMBINATION OF WING AND TAIL-MOMENT CURVES WHICH RESULTS IN INSTABILITY
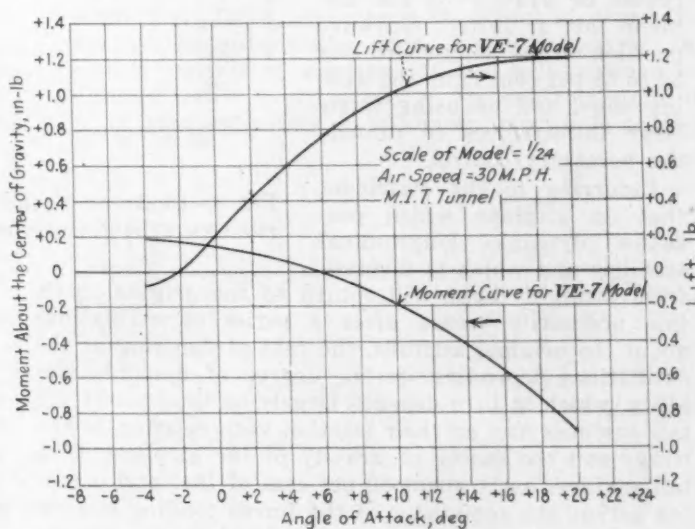
FIG. 7—CURVES OF LIFT AND MOMENT ABOUT THE CENTER OF GRAVITY OBTAINED FROM WIND-TUNNEL TEST

shows a combination of wing and tail-moment curves that indicate instability. The moment curve illustrating catastrophic instability is shown in Fig. 6.

If a plane exhibits this type of moment curve, no change in setting of the stabilizer or elevator will eliminate the catastrophic instability. Such changes move the moment curve vertically parallel to itself, changing the angles of attack at which the points of zero moment occur but not eradicating the superfluous and undesirable points of equilibrium. The moment curve must have a negative slope, or, at worst, a zero slope, and must cross the axis of zero moment but once. Change in stabilizer angle or elevator setting then moves this point of zero pitching-moment to another angle of attack, but leaves the airplane still statically stable. Fig. 7 shows the curves of lift and moment about the center of gravity obtained from the wind-tunnel test of the VE-7 airplane model. Fig. 8 illustrates the full-scale moments about the center of gravity for the VE-7 airplane.

Another way of expressing the criterion of longitudinal stability is that the pilot always should be required to exert a push on the control stick to hold the airplane in a dive, and a pull on the stick to hold the plane in a stalled attitude. In either case the airplane will return to level flight when the stick is released. This is true only at one speed for a given stabilizer angle, even in a completely stable airplane. For trimming level with free controls at other speeds, a change in the stabilizer setting is required.

It is, of course, undesirable that the stick force required to hold the airplane in a dive or in a stalled attitude shall be unduly large, as the pilot should be able to hold any desired attitude within the ordinary speed-range without excessive effort; in other words, an excess of stability is to be avoided. This is accomplished by locating the center of gravity of the airplane at a fairly rearward position on the wing chord, say 30 to 35 per cent from the leading edge, and by using fairly large tail-surfaces to provide the necessary control.

Referring to the statement that an airplane which possesses dynamic longitudinal stability and which is diverted from straight flight will return to the original path, this ordinarily occurs after a series of oscillations about the original attitude, the rate of damping of the oscillations depending on the degree of dynamic stability, which in turn depends largely on the area of the tail surfaces and on their location with relation to the wings and the center of gravity of the airplane. The tail surfaces exert about 80 per cent of the total damping action, the remainder of the forces tending toward damping of oscillation being furnished by the wings, the landing-gear and the fuselage. The last two have but very slight effect. The effect of the wings is not great; such as it is, it is due to apparent warping of the airfoil section as the wing oscillates about the center of gravity of the airplane. Since this usually
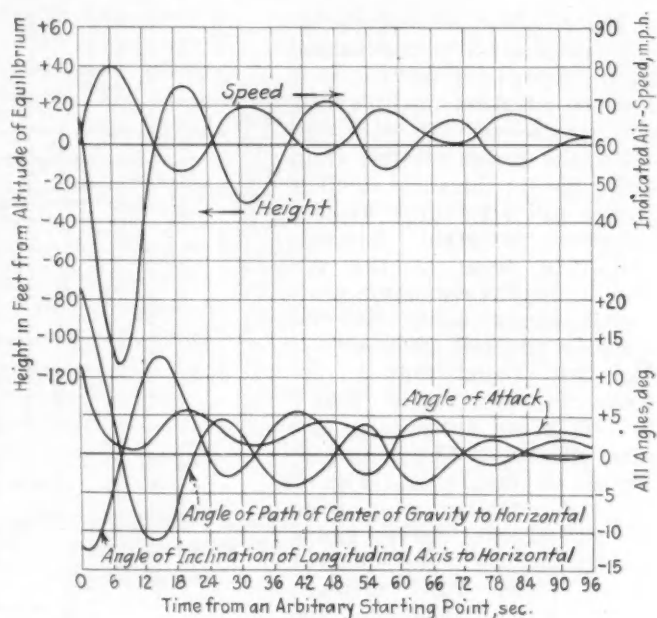

FIG. 9—CURVES SHOWING THE CHARACTER OF LONGITUDINAL OSCILLATIONS OF A VE-7 AIRPLANE WHEN DIVERTED FROM LEVEL FLIGHT

falls at about one-third of the chord from the leading edge, the rear two-thirds of the wing exerts some retarding action on the oscillation. Fig. 9 displays curves showing the character of longitudinal oscillations of a VE-7 airplane when diverted from level flight. A condition of dynamic instability can be visualized by turning the horizontal scale end for end, so that zero is at the right.

Calculations of the dynamic stability of any airplane can be made, though few complete calculations have been made. By means of these calculations the period of oscillation and the time required to damp to one-half its original amplitude are found. In the case of a dynamically unstable airplane, the latter value is of negative sign and indicates that the damping will not occur; but that, on the contrary, the amplitude will increase. In this case the calculated time is that required for an increase to double its original value.

Designers of airplanes built to date have provided good qualities of static stability and have depended on the pilot's use of the control surfaces to stop the oscillations due to any minor degree of dynamic instability. This has in general resulted satisfactorily thus far but, as airplanes become larger, complete investigations of dynamic stability, by calculation and in the wind-tunnel, will be essential. Excessive static longitudinal stability is not desirable, not only because of the large stick-forces already mentioned, but also because the pitching motions are of too uncomfortably short periods, like a ship with too great a metacentric height.
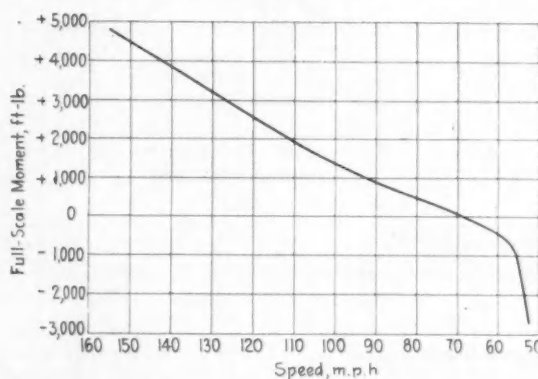

FIG. 8—CURVE OF FULL-SCALE MOMENTS ABOUT THE CENTER OF GRAVITY FOR THE VE-7 AIRPLANE

The most comfortable airplane is one having a moderate amount of statical and a large amount of dynamic stability. It apepars that, for the passenger-carrying airplane, the center of gravity should be located at about 35 per cent of the wing chord from the leading edge, and that the tail surfaces should be of rather large dimensions, as compared with usual practice. This large and effective tail gives a large damping moment; it also increases static stability, but the latter is moderated by the rearward location of the center of gravity.

Lateral and Directional Stability

Lateral stability, or stability in roll, is secured by providing fin area above the center of gravity of the airplane, by dihedral angle of the wings, or by sweepback of the wings. The action of fin area is obvious; if the airplane is sideslipping, with one wing low, the force of the air acting on the high fin-area tends to bring the wings back to level position. Fin area for this purpose is not often used in present-day airplanes, as the fuselage side-area, combined with the dihedral, takes its place. Fig. 10 illustrates the effect of fin area above the center of gravity in giving the airplane lateral stability.

Dihedral angle is the commonest means of securing lateral stability, not by opposing rolling of the airplane but by raising the advancing wing in the sideslip which accompanies a bank. Unless there is sideslip, the dihedral angle exerts no force tending to raise the low wing, and for this reason does not interfere with bank in a correct turn. The action of dihedral is as follows: As soon as sidewise velocity is set up, the low wing is meeting the air at a larger angle of attack than the high wing, and the resultant greater lift on the low wing creates a restoring moment. Fig. 11 illustrates the effect of dihedral angle in a sideslip.

Sweepback acts in much the same way as dihedral. The low wing in a sideslip is in such a position that the air flows across it in a path approximately perpendicular to the leading edge, while on the high wing the flow of air is much more oblique. Obviously, the lift on the low wing is greater. The effect of sweepback is much less than that of dihedral, a given angle of the former having only about one-sixth the effect of the same angle of dihedral.

Directional stability, or stability in yaw, is secured by providing enough fin area at the rear so that the center of lateral pressure on the airplane will be behind the center of gravity when the plane is at a small angle of yaw. This is accomplished partly by the sides of the fuselage and partly by the vertical tail-surfaces. An excess of directional stability is undesirable, however, because it makes the airplane swing about unpleasantly in rough air, makes it hard to turn with the rudder, and for the reason that too much of this sort of stability leads to what is known as "spiral instability." This defect is most noticeable when the airplane is coming down in a spiral and the excess of directional stability causes a tightening up of the spiral. This in turn increases the angle of bank, followed by sideslip, further tightening of the turn, final stalling and falling off into a spin. The cure for spiral instability is a proper degree of directional stability, and enough dihedral to prevent excessive sideslip.

Fig. 12 illustrates the action of fin area in giving directional stability. If the airplane is swung off its course, the air acts on all side or "fin" area. If the resultant force acts at B, the moment will tend to throw the airplane still farther off its course. This is directional instability. On the other hand, if the resultant force acting on the fin area acts at C, the airplane will be returned to its original course; that is, it will be directionally stable, but too much so for good directional control. The proper condition is represented by arrow A; in this case the centroid of the fin area is close to the center of gravity.

Autorotation and Spinning

The damping of the roll of an airfoil becomes less and less effective as the angle of attack increases, and becomes negative at angles beyond that of maximum lift; that is, in the region of the "burble point." When this negative damping exists, the state of autorotation is reached and only a small impulse in either direction is required to start a rotation about an axis parallel to the air-flow. This rotation of a model in the wind-tunnel will accelerate to a constant rate and continue indefinitely. This phenomenon in actual airplanes results in the autorotative spin, which is one of the greatest hazards of aviation. It also will continue indefinitely unless positive use of the controls stops it, and in some airplanes it is almost impossible to stop
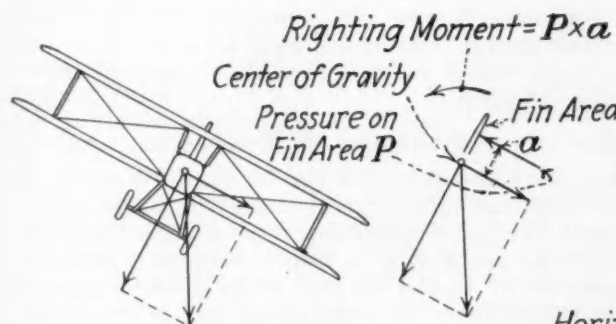

FIG. 10—ILLUSTRATION OF THE EFFECT OF FIN AREA ABOVE THE CENTER OF GRAVITY IN GIVING LATERAL STABILITY

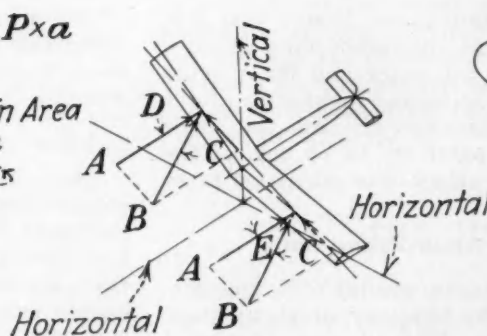Pressure on High-Fin Area Tends to Restore Wings to Level Position

FIG. 11—ILLUSTRATION OF THE EFFECT OF DIHEDRAL ANGLE IN A SIDESLIP

In the Diagram, A Indicates Forward Velocity; B, Relative Wind; C, Sideslip Velocity; D, That the Angle of Attack Is Negative on This Wing; and E, That the Angle of Attack is Positive on This Wing. It Should Be Noted that the Angle of Attack for Forward Velocity Is 0 Deg.
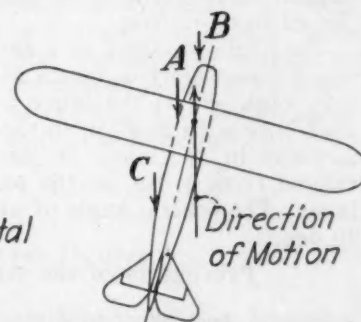
FIG. 12—ILLUSTRATION OF THE ACTION OF FIN AREA IN GIVING DIRECTIONAL STABILITY

The Centroid of the Fin Area Should Be Close to the Center of Gravity, as at A

a fully-developed spin even with full application of down elevator and opposite rudder.

While autorotation is primarily a rolling motion, this roll may occur about an axis inclined at widely varying angles to the longitudinal axis of the airplane; the angle is sometimes as low as 15 and sometimes as high as 70 deg. The motion is composed of yaw about the vertical axis and roll about the longitudinal axis. The pitching velocity is not large, yet the very large angles of attack at which equilibrium is maintained in a spin constitute one of the most surprising features of the motion. Although most airplanes have so much longitudinal stability that full-up elevator is barely enough to increase the angle of attack a few degrees above that of maximum lift, yet the airplane reaches an average angle of attack in a spin sometimes as much as 45 deg. beyond the angle of maximum lift, and holds it even though the controls are released.

The inertia moment is responsible for the foregoing peculiarity. The velocities of yaw and roll are both large, and the moment of inertia in yaw is much greater than that in roll. The precessional or inertia moment in pitch is therefore of greater importance than the moment about the other axes, and its direction is such as to increase the angle of attack. It is strong enough to counteract the restoring effect of static stability. In one airplane investigated, it was found that the inertia moment was about 5800 ft-lb., which was equivalent to a rearward movement of the center of gravity of nearly 3 ft., a relatively tremendous change and one which holds the explanation of why spinning is such a problem. This fact also indicates clearly the action to be taken by the pilot in bringing the airplane out of a spin.

Since the plane is at an abnormally high angle of attack, the first step is to bring it down to an angle within the range of normal flight. This is done by putting the elevators in full-down position, pushing the control stick fully forward and at the same time throttling down the engine to eliminate the stalling moment due to the thrust and slipstream. This converts the spin of any ordinary airplane into a dive at a normal attitude. At the same time that the elevators are put down, the rudder is placed on the side opposite to the direction of the spinning, to stop the rotation. The airplane is then brought back to straight flight by normal means, pulling back on the stick and centering the rudder controls.

The angle of attack in a spin varies from a very low, sometimes negative, figure at the outer wing-tip to a very high one at the inner tip, outer and inner being used here with relation to the helical flight-path of the airplane in the spin. In one specific case the angle ranged from 1 deg. at the outer tip to 75 deg. at the inner. The central angle of attack was calculated to be 30 deg.

Prevention of the Autorotative Spin

Several possible remedies are available to the airplane designer to prevent the tendency of an airplane toward the autorotative spin. The adoption of airfoil sections which show wind-tunnel lift-curves having smoothly rounded tops, instead of peaks followed by rapid decrease of lift force as the angle of attack goes beyond that of maximum lift, tends to prevent the beginning of a spin at those angles at which it is most likely to start. Another possibility is the use of wings

with "washed-out" angle at the tips; that is, a smaller angle of attack at the tip than elsewhere along the span. This reduces the lift on the wing tip which is the outer one in the rotation of spinning, and thus decreases the angular velocity, which, in turn, cuts down the inertia moment that holds the airplane up to the abnormally high angle of attack. Slowing up the spin has the additional benefit of tending to prevent dizziness and inability of the pilot to recover promptly.

A considerable aid toward preventing the spin is to provide for damping the yaw of the airplane while spinning. This can be accomplished by incorporating a large fin, by lengthening the fuselage, and by providing wings of high aspect-ratio. The wash-out of angle of attack of the wing tips also helps to retard the spin by building up an opposing yawing moment, in addition to its effect on the angular velocity.

It is also possible to decrease the likelihood of spins by increasing the longitudinal stability of the airplane, so that it cannot remain in equilibrium at the high angles of attack at which autorotation occurs. There is a limit to this increase in stability, however, for if the airplane is so stable that it is extremely difficult to bring up to a stalled attitude, it will be almost impossible to get the tail down for a three-point landing. The excess of stability also will interfere seriously with maneuverability, especially with turns of short radius. However, it is a fact that the greatest number of accidents due to spinning have occurred in airplanes in which the center of gravity was too far back or the tail surfaces too small, or both. It is desirable that the airplane should be sufficiently stable so that the high angle of attack necessary for spinning can be obtained only by holding the control stick back very near the limit of its travel, and that a considerable force must be exerted by the pilot to hold it there.

While a good degree of static stability tends to prevent getting into a spin, it exerts little effect toward stopping the spin after it is once established, as the inertia stalling-moment resulting from the spinning is large enough to overcome the greatest degree of static stability that is consistent with acceptable ease of control in normal flight. This inertia moment, already described, is the real cause of danger, for it is possible that it may become so large that full use of the down elevators will not restore the airplane to normal angles of attack. The magnitude of this inertia moment depends on the difference between the moments of inertia of the airplane in yaw and in roll, the former always being the greater. Anything done to make these moments more nearly equal lessens the danger of uncontrollable spinning.

Distribution of Weight

These moments of inertia can be equalized partly by proper distribution of weight along the axes of yaw and roll. Vertical distribution, such as moving a fuel tank into the upper wing, is helpful because it increases the moment of inertia in roll, while distributing the weight widely along the longitudinal axis is very detrimental because it increases the moment of inertia in yaw and makes for a greater difference. Spreading the weight along this axis thus encourages the spin and increases the angle of attack at which it occurs. The low-wing monoplane, with its concentration of large weights within a short distance along the vertical axis, and the airplane with the engine in the nose and the

cockpit near the tail, might be expected to behave badly in a spin.

In general, the rapid-spinning tendency is reduced by increase of aspect ratio, decrease in wing loading, increase of fin area, and wash-out of angle of attack at the wing tips. Increasing the rudder and elevator areas and lengthening the fuselage tail make recovery easier. The best means of prevention, however, are the use of wing curves of such characteristics that autorotation is not possible at ordinary angles of attack, and the reduction of the difference between the moments of inertia about the vertical and longitudinal axes. The necessity for avoiding wide distribution of weights along the longitudinal axis is perhaps the most important lesson that can be learned by the average airplane designer and operator from the experiments made in spinning.

The Flat Spin

During recent years the so-called "flat spin" has caused much trouble and many accidents particularly with three types of airplane that have shown themselves subject to it. In the flat spin the wings are more nearly horizontal than in the ordinary spin, sometimes not over 20 or 30 deg. from the horizontal. The rotation is rapid, but the rate of decent is fortunately not very high. When the flat-spin condition is reached it is almost impossible to recover from it by the ordinary use of the controls, that is, full-down elevator and full-opposite rudder, and the few recoveries that have been successfully made have been by combined use of the controls and the engine power.

Airplanes that have flat-spinning tendencies have always been difficult to put into a spin in the ordinary way. When started into a spin they spin normally for a few turns and then begin to oscillate, the nose finally coming up to the nearly horizontal position. Until this stage is reached, recovery can be made without difficulty by normal use of the controls, but after the change in attitude occurs the controls become ineffective. Another dangerous characteristic is that the elevator is held up to the limit of its travel with such force that the pilot is required to exert a push of as much as 150 or 200 lb. on the control stick to move the elevators into the full-down position.

The theory of the flat spin is identical with that of the "normal" spin, and its danger is due to the fact that the extremely large moments caused by the rotation overbalance the effect of the controls. There are two critical points: first, the possibility of maintaining autorotation at angles of attack between 50 and 70 deg., in spite of full use of the controls; and, second, the existence of the inertia moment which holds the airplane up to these high angles of attack in spite of the large diving moments that come into play.

The wind-tunnel model of a certain biplane with unstaggered wings showed tendencies toward autorotation over a range of angles of attack from about 17 to 28 deg. From 28 to 40 deg. the motion would not start itself nor continue unless strongly started, but if the model were given an initial rolling velocity above a certain critical value, or if autorotation were first started at a smaller angle of attack and the angle was then increased, steady rotation was possible. Beyond 40 deg. the action again became self-starting, continued at least up to 52 deg. and doubtlessly would have gone

up to 60 or 70 deg. This agrees well with the happenings in actual flight, where several turns of the spin have to be made to pick up enough speed to get past the dead region between the two zones of autorotation and to provide the inertia moment in pitch capable of holding the airplane at the large angle of attack.

Flat-Spinning of Biplanes

It is noteworthy that all the airplanes which have given flat-spin trouble have been biplanes having no stagger or practically none. This fact is readily explained. In a biplane the upper wing is largely screened behind the lower wing at extremely high angles of attack, and the loss of lift is greatly exaggerated. In the unstaggered biplane this screening is obviously more complete. The worst effects are found in unstaggered biplanes having minimum gap between the wings, for in these the interference of the lower with the upper wing is greatest.

The large force required to move the elevator control forward while in a flat spin is a consequence of the very large angle of attack, which causes the air to strike up against the elevator with extreme pressure, even when the elevator is already at the upper limit of its travel.

Wide distribution of mass along the longitudinal axis increases the flat-spinning danger, just as it does the danger of uncontrollable normal spins. One type of airplane was found to be extremely difficult to bring out of a fully developed spin, and the motion approached very closely, if it did not fully reach, the flat spin. Experiments in flight were made with this airplane, using various wing arrangements, tail settings, tail areas, and weight distributions. It was found that by loading the airplane with releasable ballast near the tail it could be made to enter a flat spin from which recovery was impossible. Upon dropping this ballast, recovery was readily effected by normal use of the controls. The loss of statical longitudinal stability resulting from the rearward shift of the center of gravity of the airlpane was, of course, influential in this case, but the effect of the increased moment of ineria about the vertical axis was extremely important.

To avoid flat-spinning tendencies, the airplane designer should give biplanes ample stagger and gap. Factors tending to damp yaw, such as long fuselages and generous fin areas, should be emphasized as much as possible without making the airplane clumsy from excessive directional stability. Finally, the weights in the fuselage should be concentrated as much as possible along a small portion of the length of the airplane, and weights located far back toward the tail should be avoided particularly.

THE DISCUSSION

GERARD F. VULTEE[a]:—We are conducting some experiments relative to the stability of the airplanes used on our air-express lines in an attempt to improve the stability for night flying. The points brought out regarding the distribution of weights along the longitudinal axis and along the wing span recall experiments made on spinning. We thought that the wing tanks in the lower wing of the Douglas O-2 airplanes contributed to the bad spinning tendency of the air-

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plane. The impression I gather from the paper is that the distribution of the weight of the tanks over a long span of wing tends to cure the flat-spinning tendencies. Am I right?

LIEUT.-COMMANDER L. B. RICHARDSON:—I seem to have been misunderstood. I referred to the distribution of the weight along the vertical axis rather than to distribution along the span of the wings; that is, to the axis about which the yaw takes place, as the swing from side to side takes place about the vertical axis. Distributing the weight vertically has a tendency to decrease the likelihood of a spin, but I believe distributing the weight along the span would not have much effect. I agree that the tanks in the lower wing would make the tendency worse for the airplane to spin; but tanks in the upper wings have a tendency to prevent spinning. The point I made was that the low-wing monoplane, which concentrates most of the weight at one spot on the vertical axis, will very likely spin worse than when that weight is distributed.

DR. CLARK BLANCHARD MILLIKAN[5]:—The actual location of the center of gravity is so much a matter of what the pilot wants that its placement is more a matter of experience than of theory. In your experience, what was the most forward position for the center of gravity in which the performance of the airplane was still satisfactory?

LIEUT.-COMMANDER RICHARDSON:—The most forward position of the center of gravity in the Martin torpedo plane was 19 per cent of the wing chord when lightly loaded. To be able to make a good landing with this plane, 200 lb. of sand is carried in the tail.

DR. MILLIKAN:—Is any difficulty experienced with that plane due to rough riding, or is the only difficulty in getting the tail down?

LIEUT.-COMMANDER RICHARDSON:—Gusts have little effect because the plane is so large. The condition is bad in that the tendency is toward making landings with the tail high. Hardly any pilot lands one of these airplanes normally. They are equipped with a peculiar stabilizer-adjustment mechanism and the same motion of the ratchet makes the tail or the nose heavy. Recently, a pilot on his first solo flight operated the stabilizer adjustment wrongly; his key slipped over to the position "tail up" and the airplane went over on its back when its wheels struck the ground. This illustrates another bad feature of having the center of gravity too far forward in a large airplane.

Effects of Various Constructions

J. J. MURRAY[6]:—What is the comparative correction against yawing that can be expected from a fuselage that has a rounded rear end rather than one with vertical flat surfaces?

LIEUT.-COMMANDER RICHARDSON:—I believe that a greater effect is produced by flat sides, but not so much as might be expected. There is almost as much effect from a rounded fuselage of equal projected area as from a flat-side sharp-cornered-fuselage tail.

MR. MURRAY:—Would the fin surfaces be very similar?

LIEUT.-COMMANDER RICHARDSON:—There is a slight difference, but not so much as the appearance would indicate.

CHARLES H. PAXTON[7]:—What is meant by the percentage of the vertical position of the center of gravity? Is it the percentage of the chord?

LIEUT.-COMMANDER RICHARDSON:—It is the percentage of the chord; in the case of a biplane, it is the percentage, above or below. the mean chord.

G. E. RUCKSTELL[8]:—What effect would a retractable landing-gear have upon the spinning tendency of a low-wing monoplane?

LIEUT.-COMMANDER RICHARDSON:—In theory it would increase the likelihood of a spin and probably make the spin worse, because the weight of the landing-gear would be still further concentrated along the vertical axis. It has the effect of grouping all the weights, which tends to increase the spinning tendency.

A MEMBER:—Why is it necessary to have a variable surface on a fixed stabilizer? If the plane were correctly designed, it seems that it would not be necessary to shift the stabilizer.

LIEUT.-COMMANDER RICHARDSON:—The war airplanes had no stabilizer adjustment, but they could not be flown hands off except at one throttle-setting. Planes with a fixed stabilizer can be flown with hands off at one position only. The adjustable stabilizer enables the pilot to fly at any speed with zero force on the stick, and to make the plane balance with the tail slightly heavy to assure easy landing. Every modern airplane has an adjustable stabilizer, especially those which are to carry varying loads and are to be flown at varying speeds.

L. MACLEOD[9]:—Is any advantage gained in locating the engine behind and above the rear wing of the plane as in the Savoi-Marchetti design?

LIEUT.-COMMANDER RICHARDSON:—The location of the engine in the pusher type of airplane decreases the distribution of the weight along the longitudinal axis, but this creates a rather bad condition as the line of thrust is so far above the center of resistance that the airplane does not balance well under full power or with the throttle closed. Any airplane having its engine mounted in such a high position is very tail-heavy when the engine is throttled down or when the engine fails; a strong push on the stick is necessary in case the engine fails. The Liberty HS airplane was well known on account of this peculiarity; instead of landing it by pulling the stick back, the pilot landed by letting it go of its own accord. Any airplane having the engine mounted high above the center of resistance will have the same tendency. But there is no objection to having the engine located behind the wing.

Work of the Materiel Division of the Army Air Corps

By Brigadier-Gen. W. E. Gillmore[1]

ORGANIZATION of the Materiel Division and the division of work among the five major sections and of the several branches of the experimental-engineering and procurement sections are concisely explained. Activities carried on by the Division are considered as divided into research work and development work, and the sorts of investigations included in each class are indicated. Mention is made of some of the major projects under way, such as study of wing-flutter, a more effective coolant for water-cooled engines, propeller tests, development of navigation instruments and radio reception under flying conditions, the study of air-flow, and day and night aerial photography.

Facilities provided by the new structures and laboratory equipment at Wright Field for the conduct of all the research, experimental and test work of the Division are illustrated and described. The author points out that the primary objective of all phases of the work is National preparedness, that the Government is better able to finance the costly research and development facilities and activities than are the commercial organizations, and that the industry derives the benefits later.

Loss of personnel to private organizations has impeded progress in some of the work of the Division but this has been compensated for by the very rapid development of materials and aeronautic equipment by the industry. These products are brought to the Materiel Division for test, so the Air Corps derives the benefit of the commercial work done by men who leave the personnel.

TODAY, in spite of a great amount of work which is being done along lines of disarmament of nations, considerable thought and energy are being devoted to adequate National preparedness. In America we do not desire to have military and naval equipment in such quantities that we shall appear in a challenging attitude; that is most distant from our thoughts. However, we do believe that we should have efficiently trained military and naval units which would be only large enough to render usual peacetime services and to form the nucleus of a defensive organization in the event of an emergency. All arms and branches of National defense depend more and more each year for their efficient operation upon services rendered by our flying men. The Artillery, Infantry and Chemical Warfare branches in particular recognize the indispensable assistance of the Air Corps.

Some of the lessons we may learn from the first quarter century of real aeronautical development include knowledge that much of this development work must be accomplished in a leisurely, thoughtful manner by highly trained engineers and highly skilled mechanics. In addition, we have learned that much attention must be given to developing sources of supply of raw materials as well as to the careful preparation of these materials all along the line until the product is finished.

Organization of the Materiel Division

The Materiel Division of the Army Air Corps is charged with the task of furnishing our Army airmen with all necessary equipment, which must rank second to none. In organization, the Materiel Division is made up of five major sections, including the administration, experimental engineering, procurement, field service, and industrial war-plans sections. Each of these sections has its own special problems to solve and its own personnel to train along these lines.

The administration section, as the name implies, includes many important activities, such as the station supply, the flying, the technical data, patent liaison, and medical branches and the management of all offices. This section is charged with the safe-keeping of all technical reports and other data secured as a result of experimental work.

The experimental engineering section includes the airplane, powerplant, armament, equipment, lighter-than-air, and materials branches. In this section the actual research and development work is carried on.

The airplane branch is concerned primarily with study of the structure and performance of the airplane. Theoretical structural analyses are made and airplanes static tested.

The powerplant branch passes upon engines and the accessories pertaining thereto. In its laboratories many engines are tested for performance and endurance. A considerable amount of research work is carried on by this branch. Some of the more recent researches include comparative tests of antiknock fuels, testing of various liquids as cooling mediums in engines, and tests on many different parts such as cylinders, valves, and carbureters.

The equipment branch is charged with the development of dozens of items of miscellaneous equipment, including cameras for all different types of photography, parachutes, life preservers, aviator's clothing and instruments.

The lighter-than-air branch deals with various types of observation balloons and the small class of dirigibles.

The duty of the materials branch is to test and report upon all materials selected for use in the various parts of airplanes and airplane equipment. This branch tests

oils, gasoline, fabrics, rubber, wheels, airplane ribs, brace wires and other small parts. Following the failure of a part, this branch gives it a microscopic examination and often a chemical analysis to determine the composition of the material. Research is also carried on in this branch into the nature of new types of alloy. For several years experiments in aluminum and magnesium alloys have been carried on.

The armament branch is charged with the selection, testing and installation in aircraft of all such items as machine guns, bombs, bomb racks and bomb sights.

The procurement section issues specifications showing the requirements of various forms of aircraft, follows the development closely, and maintains a set of accurate engineering records. The various proposals, bids, orders and contracts are executed by this section. A very important branch of this section is that for the inspection of airplanes and engines at contractors' plants during their manufacture and assembly, as well as the inspection of finished products within the Materiel Division itself.

The field-service section is in reality the liaison unit between the experimental-engineering section, the Air Corps repair depots and service organizations in the field. It controls the supply of airplanes, engines and all spare parts, and issues orders on technical equipment.

The industrial war-plans section supervises the investigation of sources of supply of materials used in aircraft construction. Through its six different offices scattered throughout the Country, it makes a survey of the industries particularly fitted to supply complete units or various parts needed in the manufacture of airplanes on a production basis. This is an extremely important work and one which must necessarily be done slowly and carefully.

Included in all activities of the Division, repair depots and various offices located in different parts of the Country, we find approximately 130 commissioned officers and nearly 3000 civilian personnel employed.

The Two Types of Activity

The activities at Wright Field might be considered as being divided into two types—research work and development work. It is often difficult to draw the line between these two, yet each has its definite place and its effect upon the general progress of aeronautics.

Research work might be assumed to include investigations of a long-time nature, the results of which may not be incorporated in production articles for several years. Such work may include the producing of a new alloy of great strength and light weight which will find many varied uses. Again, research might include such problems as the penetration of fog by light-rays of dif-

FIG. 1—BUILDINGS ON WRIGHT FIELD AS SEEN FROM THE AIR

Facing the Semicircular Drive in the Left Center Is the Long White Administration Building. Directly Behind It Are the Saw-Tooth-Roof Main Laboratories for Tests of Equipment and for General Development Work. Across the Drive and to the Rear Right of the Main Laboratories Is the Final-Assembly Building Where Airplanes Are Prepared for Flights; and Adjoining It Are Shops for the Various Parts Going into Final Assembly. In the Large T-Shaped Structure in the Right Center Is Housed the Powerplant Section and a Very Modern Testing Laboratory. Three Large Hangars Are Located in the Immediate Foreground
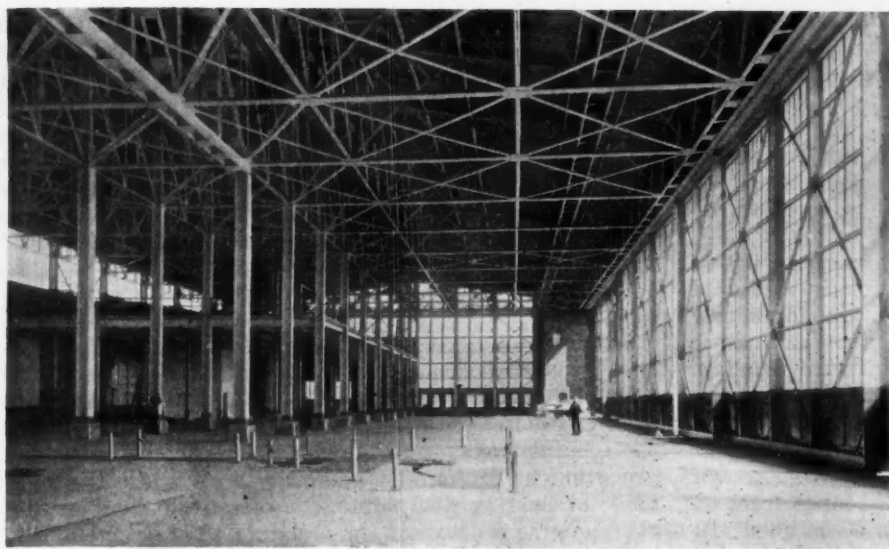
Fig. 2—(Left) Interior of Final-
Assembly Building, Showing Large
Set of Scales in the Foreground.
(Right) Static-Test Room in Final-
Assembly Building, Showing Key-
stone KHB-3 Multispar Wing Un-
der Sand-Load Test

ferent wave-length. It might in-
clude work relative to wing-flutter,
something we have heard compara-
tively little about but which may
have been responsible for certain
regrettable accidents.

Development work, as the name
implies, deals with the improving of equipment whose
general design is already laid out. It may include the
developing of a new method in the manufacturing of
certain articles. The development work, in general,
consists of purchasing some article, such as an airplane
or engine, or some item of equipment, from a commer-
cial organization, giving that article as severe and
painstaking tests as possible, and then cooperating with
the manufacturer in remedying the troubles which are
so often experienced. To develop an airplane means to
give it a thorough performance-test to ascertain its
ability to climb quickly, its forward speed, and the load
it will carry. The strength, flying qualities and general
fitness for the particular type of work desired must
also meet certain very definite requirements. Changes
must be made and many tests repeated.

During the period in which the aeronautic industry
was young and struggling for existence, the experi-
mental building of engines or airplanes by the Govern-
ment was generally frowned upon, as it was felt that
the industry should be awarded the orders. With the
changing conditions, it seems as though the manufac-
turers are anxious for the Government to continue
many experiments and participate in researches along
lines which commercial concerns generally are unable
to carry on. A great amount of research work remains
to be done in perfecting our aerial-transportation sys-
tem. Research, when carried out by the Government
and the information secured is made available to manu-
facturers, is unquestionably an aid to the industry. The
ability to test a propeller of 40-ft. diameter, under vari-

ous load and speed conditions,
should prove a great advantage.

Torsional Flutter Investigation

Among many interesting re-
search projects, one relative to
wing-flutter offers a great field for
investigation. One of the most re-
cent demonstrations of wing-flutter
in late years was the failure of the
French monoplane, the Couzinet,
piloted by Maurice Drouhin. Short-
ly before his death as a result of
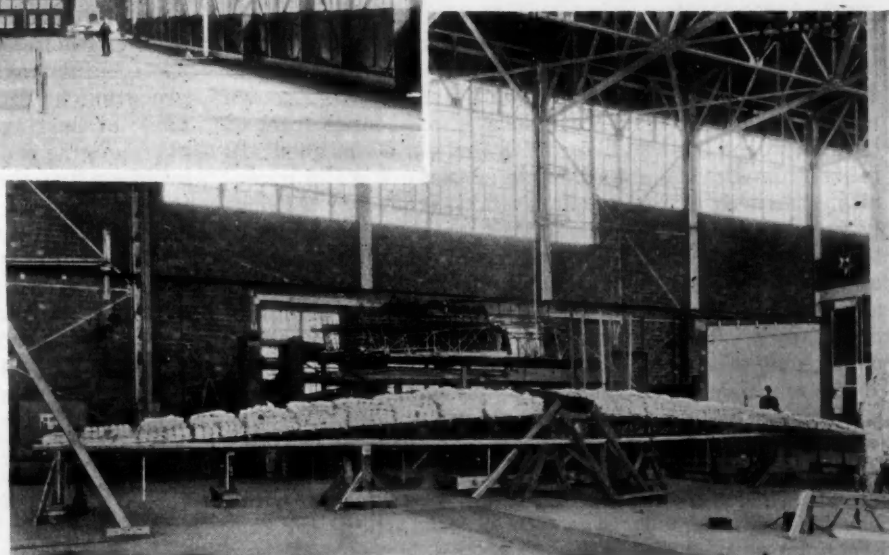
its crash, this famous pilot stated that the wings began
to vibrate and continued to build up these vibrations
until he estimated that the wing tips were moving 4 or
5 ft. This condition eventually caused the disaster which
followed. With the steadily increasing size and speed
of transport and commercial airplanes, the necessity
of these investigations becomes of increasing impor-
tance.

An investigation now being carried on at Wright
Field pertains to the cause of wing-flutter and the de-
sign to preclude flutter in airplane wings, propeller
blades and control surfaces. Experiments show that an
airfoil will flutter at any angle of attack, but at a lower
velocity at the angle of zero lift and at the burble point,
and that the tendency to flutter depends on the aero-
dynamic and structural characteristic of the wing, such
as the thickness and camber of the section, location of
the center of gravity, rigidity, and so on. The study is
being made on wind-tunnel models in our 5-ft. wind-
tunnel to determine the qualitative and, to some extent,
the quantitative effects of the various factors men-
tioned on the air speed required to precipitate the flut-
ter. Two distinct types of flutter have been noted;
namely, (a) torsional vibration or flutter, and (b) ail-
eron flutter.

Aileron flutter is a condition of instability pertaining
to the interaction between the aileron and the wing.
This type of flutter, so far as experimentation and prac-
tice to date show, is prevented by statically balancing
the aileron about its hinge. The wing, however, is still
susceptible to torsional flutter even with the aileron

balanced. The problem has been, and is now being, studied by several European scientists. The solution to the aileron-flutter problem was first proposed by A. G. Von Baumhauer and C. Koenig in 1923, and was confirmed in practice by A. H. G. Fokker. The investigation on torsional flutter at the Materiel Division has not proceeded far enough to draw definite conclusions.

Wright Field Embraces Nearly 5000 Acres

Rather general misunderstanding has existed relative to the names of the aeronautic activities centered around Dayton. During the war period and for nearly a decade thereafter, two main Government aeronautic activities were carried on in the vicinity of Dayton. McCook Field, the experimental station, known as the Engineering Division of the Air Corps, was located within the city limits; in fact, within one-half mile of the very heart of the city. The other activity, known as Wilbur Wright Field, was located on a large tract of land adjacent to the village of Fairfield, Ohio, about 12 miles from Dayton. As the use of McCook Field necessitated heavily loaded airplanes taking off over a thickly populated area, a decision was made to move all activities to a new site. The citizens of Dayton purchased and presented to the War Department a tract of 4562 acres of ground, so that the engineering division might be retained. This large tract really is divided into two parts; one, of approximately 750 acres, is the new home of the engineering division, now known as the Materiel Division. This is located about six miles east of Dayton in the protected area of the Huffman Conservancy Dam. It is a level tract sufficiently large for a runway nearly one mile in length in any direction. We have one runway 6000 ft. long. It is so smooth that a light car can be driven on it at 60 m.p.h. The name McCook was accordingly dropped and this new site given the name of Wright Field in honor of both Orville and Wilbur Wright. A 20-acre tract of high ground adjoining has been set aside as a site for the Wright Memorial Park.

The other portion of ground, about 3800 acres in extent, includes the buildings of the former Wilbur Wright Field, which is now known as the Fairfield Air Depot and used for the repairing of service airplanes of various types. On this location stands the hangar which housed the world's first successful airplane. It was on this site that the greater amount of development work was carried on by the Wright brothers. The low lands of this larger tract are very useful as a bombing and machine-gun range for the training of pilots, as well as for much experimental work with new forms of armament equipment.

Buildings and Laboratory Equipment

The many buildings erected on the new site adequately answer the needs of a large uptodate experimental station. The administration building, a structure 540 x 55 ft. facing the semicircular drive in Fig. 1, houses the administration offices, such as the legal branch and procurement section, in addition to an auditorium capable of seating 800 persons, a restaurant and an airplane-engine museum. Immediately to the rear of this building are the main laboratories, where 144,000 sq. ft. of floor space is housed under a single saw-tooth-type roof. In this building experiments are made with hundreds of different items of equipment and much development work in general is carried on. The blueprint department, airplane-structures unit, navigation-instruments units, parachute unit and others are housed here.

North of the laboratories building, to the right of it in the photograph, is a beautiful structure known as the final assembly, which is a large building used for the final preparation of airplanes for flight. Smaller buildings housing the sheet-metal shop, machine-shop, wood-working shop and wing-doping shop adjoin or rather connect with this building, supplying conveniently the various parts going into the final assembly of an airplane. A very large set of scales, laid out in such a way as to conveniently weigh the largest airplanes in use in this Country, is located in the final-assembly building, an interior view of which is presented in Fig. 2. They are of the platform type and are capable of determining the weight upon each wheel and the tail-
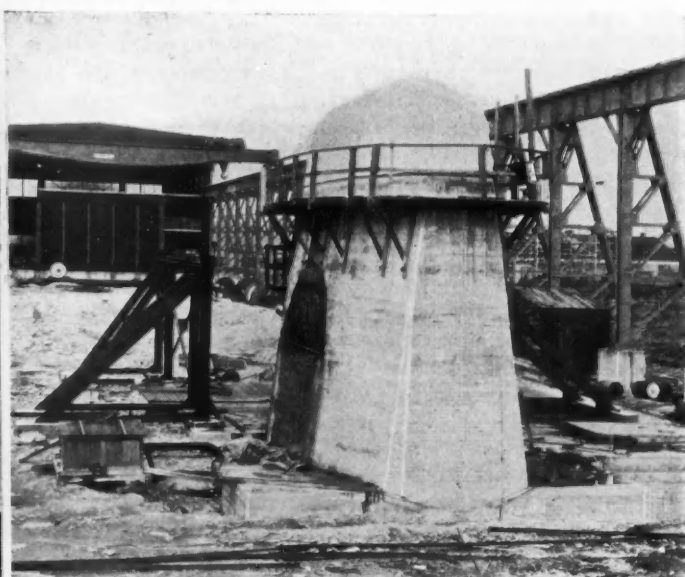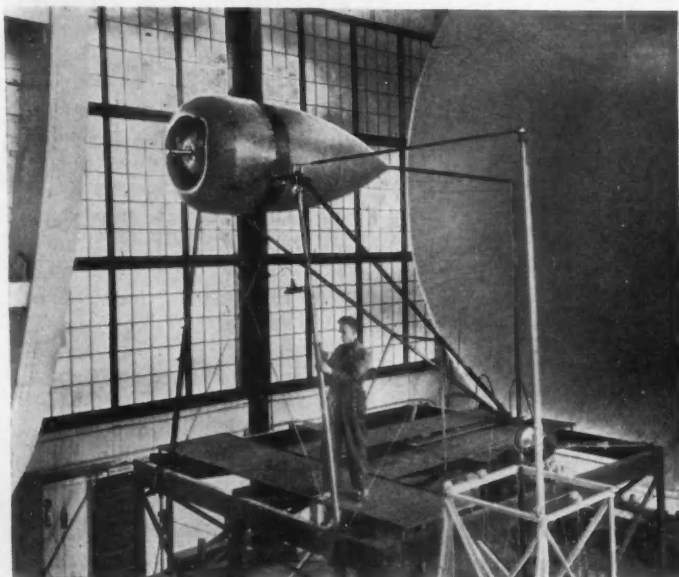

FIG. 3—(LEFT) PROPELLER RESEARCH TUNNELS ARRANGED SO THAT THE SLIP-STREAM OF ONE CAN BLOW UPON THOSE IN THE REAR, SIMULATING FORWARD-VELOCITY CONDITIONS. (RIGHT) EAST STAND FOR PROPELLER WHIRLING TESTS IN WHICH PROPELLERS CAN BE TESTED TO DESTRUCTION

skid of the plane. One corner of this building is used as the static-test department, also shown in Fig. 2, in which airplanes are actually loaded to destruction to determine whether they comply with the strength requirements of the Government. In this corner we learn which are the weaker parts of the plane, strengthen them, and retest time and time again. This procedure is not only an excellent check upon the theoretical computations of stresses in new and experimental designs but actually furnishes data from which new formulas can sometimes be derived.

Facing the final-assembly building, the powerplant branch occupies a large T-shaped structure comprised of offices for the engineers there employed, an overhaul and reconditioning shop, and a very modern testing laboratory. In the testing laboratory are three dynamometer stands, each capable of testing engines up to 1500-hp., and three stands of 1000-hp. capacity in a single unit. Two stands of the 300-hp. class and five individual stands are used for the testing of equipment on single-cylinder universal test-engines. The horsepower, gasoline and oil consumption of engines are accurately measured and data relative to temperatures, wear and vibration are obtained. The electrical energy generated by the test engines is conducted through heavy cables to the attic, where it is dissipated in large resistance units, as power from this laboratory is necessarily so irregular that no way has been found to efficiently put it to use.

The most interesting item of equipment in the powerplant laboratory is the cooling device used in testing air-cooled engines of high horsepower. Propellers driven at both ends of an underground channel produce an air pressure which finds outlet around these engines, thus giving them the desired amount of cooling and producing at times air velocities as high as 120 m.p.h., while power-calibration runs are being conducted on the electric-dynamometer stands. The endurance test-runs are often conducted on the torque stands, using a propeller on the engine shaft. The air in the laboratory is standardized or conditioned to a temperature of 60 deg. fahr. before entering the carbureters. A system is also provided which permits of air being supplied to the carbureters at varying pressures, the quantity of this air being measured by meters in the air ducts. This scheme simulates engine operation at altitudes where the air pressure is much less than at sea level. Tests and calibration runs of various commercial engines are frequently conducted here for the Department of Commerce.

Elaborate Propeller-Test Unit

The propeller-test unit is one of the most important, and also one of the noisiest, units on the field. Failure of a propeller may easily wreck an engine and possibly cause a disaster. It is imperative that propellers be constructed of the best obtainable material by the best workmen available and given exhaustive tests to destruction. With the use of increasingly higher-powered engines of both the geared and the non-geared type, larger and stronger propellers must be provided. Our new apparatus, some units of which are shown in Fig. 3, provides for one test stand of 6000-hp. capacity having clearance for a 40-ft.-diameter blade, a smaller one of 3000-hp. capacity at 1800 r.p.m., and one of 2500-hp. capacity at the high rotative speed of 4300 r.p.m. These stands are arranged so that the slipstream of one may be blown upon those in the rear, simulating forward-velocity conditions. Current for the operation of these stands is furnished by the power room at 33,000 volts. Transformer capacity is sufficient to operate any two stands at full capacity at the same time, 6000 volts being used on all alternating-current machines. The regulation of motor speed by varying the frequency of the current supplied is necessary in propeller testing and has necessitated the construction of special motors. The current enters the station at 60 cycles and is transformed to direct current by means of a motor-generator set. The direct current in turn drives a second motor-generator set at variable speed, so that alternating current of a desired frequency is supplied to the driving motors.

The equipment of the propeller-test unit cost more than $550,000. Only a great government like ours could afford to invest that sum in equipment of this character. The unit is there for the use of propeller makers who bring their propellers to the Division to be tested. I hope and believe it will not be necessary for a commercial concern ever to invest in any equipment of this kind.

The new wind-tunnel installation comprises a 5-ft. tunnel, the air-speed of which may be operated as high as 240 m.p.h. A smaller 14-in. tunnel is
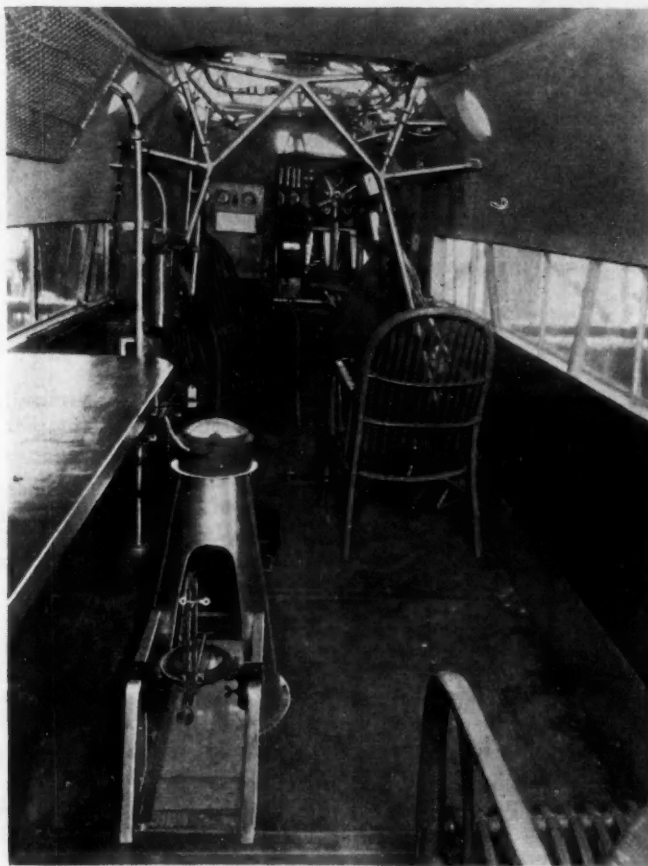

FIG. 4—INTERIOR OF FLYING NAVIGATION LABORATORY

This Has an Observation Room for Taking Sextant Readings and Is Equipped with Smoke Bombs and the Latest Compasses, Drift Meters, and Other Instruments. Curtains Can Be Drawn Down Around the Pilot so that He Can Be Given Long Periods of Training in Blind Flying

FIG. 5—THIRTY SQUARE MILES OF TERRITORY, INCLUDING WRIGHT FIELD IN THE LEFT CENTER, PHOTOGRAPHED FROM AN ALTITUDE OF 32,000 FT.

capable of speeds up to 500 m.p.h. These tunnels are in daily operation at the new field. It is hoped that funds will be available later to install a 10-ft. tunnel for use with larger-scale models. Both wire and spindle-type balances can be used. A remote-control system makes possible the control of the air velocity from the "cabin" housing the balances. Air-flow is now being studied by means of slow-motion pictures. Smoke is sometimes introduced to flow around the model airplanes or wing sections and its action photographed.

Flying Radio and Navigation Laboratories

Two tri-motored Fokker airplanes have been specially equipped for the study of navigation and of radio reception, respectively, under flying conditions. The radio airplane, or the "flying laboratory" as it is known, plays a very important part in the testing of most of our radio equipment. Various experiments in connection with the radio beacon are made in this airplane. The spacious cabin provides a work-bench about 2 ft. wide and 8 ft. long on which the various forms of experimental apparatus are mounted. Experiments are being conducted with a sensitive altimeter of the radio-sounding type in an effort to develop an altimeter capable of indicating altitude above the ground beneath

rather than the altitude above the starting point of an airplane.

The reports of virtually all long-distance pilots are unanimous in stating that instruments are absolutely essential for periods of blind flying. Perhaps the greatest of single navigation achievements has been the flight of the Southern Cross from San Francisco to Australia. The pilots reported that, without the aid of instruments, a radio operator and an expert navigator in this flight, they would, in all probability, have met disaster in the waters of the Pacific. Another point these pilots made is that experience in blind flying is indispensable to a pilot engaged in this kind of flight. The navigation airplane used at Wright Field, shown in Fig. 4, is equipped with curtains which can be drawn down, and the pilot is given training in blind flying for long periods at a time. This plane is also equipped with most up to date compasses, drift meters, smoke bombs, and even an observation room from which sextant readings can be taken conveniently. This plane at present is engaged in a series of cross-country flights throughout the United States to test the accuracy of new instruments and give several officers of the Service unusually good instruction in navigation.

Every effort is being made to develop as rapidly as

possible apparatus suitable for high-altitude observation work. Electrically heated goggles, clothing, and moccasins are being experimented with, superchargers are being fitted to engines to enable them to maintain their horsepower at altitude, and special photographic equipment is being tried out. One of the latest practical uses of aerial photography, as found by the Materiel Division, is the photographing of the waters of the Mississippi River at flood time and the flooded areas in the Dayton Conservancy District. High-altitude photography undoubtedly will be used to a great extent in mapping large areas.

Fig. 5 shows a view taken from an altitude of 32,000 ft. and embracing about 30 sq. miles, including Wright Field in the left center. A similar photograph taken near Rushville, Ind., by Captain Stevens, photographic officer of the Division, with Chief Test Pilot Street at the controls, was made at an altitude of 38,000 ft. and in a temperature of —60 deg. fahr. Liquid-oxygen tanks, tubes and face masks were required by the pilot and photographer.

In another flight, a flashlight photograph was made at night from a height of 6000 ft., the time required for exposing the film, developing it in flight and dropping it to the ground being 8 min. from the exploding of the flashlight bomb.

Another of the interesting researches that the Division has undertaken is an investigation to determine whether some liquid can be substituted for water in the cooling system of aircraft engines. Many different liquids have been experimented with in these laboratories during the last 10 years in an effort to find some available liquid which would have the characteristics necessary for this work. This liquid must have a high boiling-point so that it can transmit the excess heat from the engine through a smaller and lighter radiator. The latest liquid to be tested successfully in a 50-hr. endurance ground-test has been ethylene-glycol. This liquid, which is one of the polyhydric alcohols ($CH_2OH.CH_2OH$), has a boiling-point when pure of 387 deg. fahr. The 50-hr. ground-test in a well-known aircraft engine has recently been supplemented by a series of full-flight tests in one of the Curtiss P-1B airplanes. By the use of this liquid it seems possible to reduce the size of an ordinary radiator by 75 per cent and to make a corresponding reduction in the amount of coolant. In the case of the Curtiss pursuit airplane, shown in Fig. 6, the installation weight was reduced about 90 lb., the entire resistance of the airplane was reduced approximately 10 per cent and the speed naturally increased.

Although much work is yet to be done in this connection, the use of a substitute for water seems to offer one of the greatest opportunities for the improvement of the present water-cooled type of engine. This new development reduces the weight of a standard water-cooled
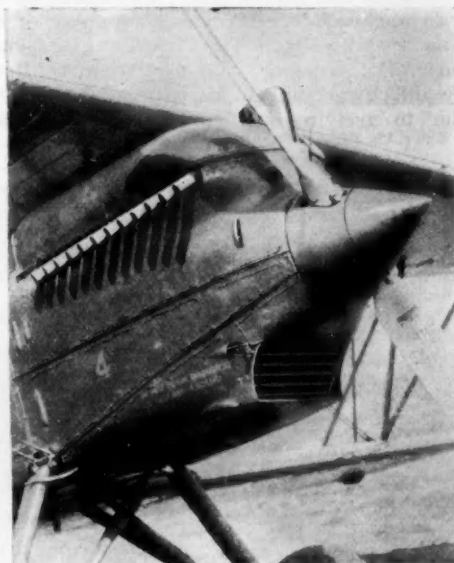

FIG. 6—CURTISS PURSUIT PLANE EQUIPPED WITH SMALL RADIATOR FOR USE OF ETHYLENE-GLYCOL

Use of This New Coolant Makes Possible a Reduction of 75 Per Cent in Radiator Size, 90 Lb. in Weight of the Airplane and 10 Per Cent in Air Resistance of the Entire Airplane

airplane about 100 lb. and adds about 11 m.p.h. to the high speed of the craft.

Work on this new coolant has been going on for a long time at the Division, and similar experiments have been carried on by the Navy. Ethylene-glycol has the advantage of being an antifreeze liquid. We consider this one of the outstanding developments that have been made at the Division in a number of years.

In the near future the Materiel Division will have completed the buildings planned on its new site and be ready to devote its entire attention to the needs of the Service. It is earnestly hoped that appropriation by the Congress of adequate funds with which to carry on a large amount of development and research work will be continued. The personnel of the Materiel Division is extremely interested in the work and it is felt that the engineering information derived will fully justify the necessary expenditures. The work is absolutely essential to the military establishment, and we believe that much of it will find, as in the past, a ready market in the various commercial organizations. The product for which the Division is most noted today is perhaps the large number of alumni, or men now scattered throughout the industry who have received much of their experience and training in the Materiel Division.

The industry, growing as it is, has come to Wright Field for much of its personnel. This has slowed down our work in the powerplant laboratory and in the other laboratories, but we feel that every one of our men who has gone into the industry is still performing a part for the Government in the production of things we may need for National defense. We get the results of their labor later, for their products are brought to Wright Field, as a rule, directly or indirectly.

A few years ago the sources of supply for aeronautic equipment could be counted almost on the fingers of two hands, yet the chairman of the Aircraft Show in Detroit in April, 1929, told me that there were 105 exhibitors in that show and that it was necessary to refuse space to 142 applicants. We in the military Service are intensely interested in this growth, because it is a great asset to us.

Much of the development work in the past has been paid for out of production funds, but I think we have come to the time when aeronautic engineering concerns will not look with favor upon carrying over into possible production the cost of development work that has not been paid for. I think they much prefer to go back to the system of contracting for experimental work to be paid for whether or not the article goes into actual production. Decision has been reached by the Chief of the Air Corps, after careful study, to recommend to the Congress that in making our estimates, we be allowed to ask for funds to pay for our experimental work independently of production funds.

Notes on the Graf Zeppelin and Her Transatlantic Attempt

By Alfred F. Masury[1]

A GENERAL description is given of the Graf Zeppelin and the author relates some details of his observations as a passenger during the attempted flight from Friedrichshafen, Germany, to America. The route chosen was down the valley of the river Rhône, over France to the Mediterranean Sea. They proceeded well until, near Cape Nao, Spain, engine trouble developed and the commander, Dr. Eckener, decided to return. Although many difficulties were encountered during the return prior to arriving at the landing-field at Cuers, France, the author states that Dr. Eckener and his crew were at all times calm, that no panic occurred and that the ship did not lurch. Numerous unsuccessful attempts were made to land before the ship was finally brought to earth at Cuers.

The Graf Zeppelin is powered with five 12-cylinder, 550-hp. Maybach-Zeppelin VL-2 engines which are directly reversible and can operate on either liquid or gaseous fuel. They are mounted in individual power-gondolas, slung beneath the hull in a staggered position so that the propellers

Fig. 1—Route of the Graf Zeppelin to Cape Nao, Spain, and Return to Cuers, France

THE Graf Zeppelin left Friedrichshafen, Germany, early on Thursday morning, May 16, 1929. It was a pleasant day and there was no wind. Our trip from the hotel to the hangar was by motorcoach and, on arrival, all the passengers climbed the steps and entered the passenger compartment. It was just like boarding a steamship. Weather reports were being received constantly and Dr. Hugo Eckener, the commander, decided to go down the valley of the river Rhône, over France, as shown in Fig. 1, rather than to go over the North Sea where wind was reported. Fig. 2 is a photograph of Dr. Eckener. The airship was taken from its hangar by about 200 men and, as we arose with it from the ground, cheers enlivened the start. The ride over the lakes and down the valley of the Rhône was delightful.

The arrangement of the ship provides separate com-

are not affected by the backwash of the propellers ahead. According to the author, the engines afford the airship a cruising radius of about 6100 miles; each weighs 2450 lb. and their total of 2750 hp. gives the ship a cruising speed of about 72 m.p.h. in still air and a top speed of 80 m.p.h.

Describing the engines somewhat in detail, the author remarks the feature of direct reversibility which is accomplished by means of a simple shifting of the camshaft rather than by the former means of using gears. A compressed-air starter can crank the engine either clockwise or counter-clockwise, and the power can therefore be used to move the ship forward or astern, facilitating its maneuverability. Other parts of the engine are commented upon and their important features emphasized, and a brief outline is given of the advantages of using blau gas as fuel. The liquid-fuel consumption at full load is stated to average 0.451 lb. per hp-hr., as compared with 0.551 lb. per hp-hr. for the ordinary engine that is used for aviation purposes.

partments for control (Fig. 3), navigation, and wireless telegraphy (Fig. 4). These are interconnected by telephone and signaling systems. Various devices, such as altimeters and speed indicators, are provided for navigating purposes. Among these is included a device for determining the elevation of the ship above the ground. A gun is fired from the ship, the echo as reflected from the ground is caught by a microphone and transferred electrically so that the elapsed time is recorded, and from this the distance above the ground can be calculated. Electrically actuated altimeters indicate which end of the ship is the higher. Another device measures the speed of the ship by recording the time required for its shadow to pass over a given point on the ground.

The power for wireless telegraphy normally is obtained from a generator operated by a propeller being dragged through the air on the outside of the main compartment; but, for emergencies such as are en-

[1] M.S.A.E.—Vice-president and chief engineer, International Motor Co., New York City.

countered when the ship has lost headway, a small air-cooled gasoline engine is provided which can be run to supply wireless power when the ship is stationary.

The passenger staterooms (Fig. 5) are very similar to the drawing rooms on a railroad sleeping-car. Upper and lower berths are provided and the lower berth can be transformed into a couch for day usage. Each stateroom has a sliding door, a clothes closet, a small writing table, and a small window. Two passengers are assigned to each, and the compartments are located on both sides of the ship. One walks forward from the passenger section through a long hallway into a salon (Fig. 6) which is used for dining and recreation. It has windows on either side, there being only two posts in the center. For meal service, the tables are assembled into one long table at which 20 people can be seated. The ship's galley is shown in Fig. 7.

The Graf Zeppelin has great flexibility. Each part is of sufficiently light construction so that it will yield and permit the strain to be transferred to some other

FIG. 2—DR. HUGO ECKENER, COMMANDER OF THE GRAF ZEPPELIN

part. Simplicity of detail is very noticeable. Experience over a considerable period, in which about 50 Zeppelins of different sizes have been built, has resulted in the elimination of complicated details; for example, to provide power for the electric stoves, a generator equipped with a propeller is mounted on an arm or bracket and swung outside the galley into the airstream.

All but four of the passengers were reporters or newspaper men. On account of the dictaphones and typewriters and the effort of these men to get their reports ready and transmitted to their papers, the salon seemed like a newspaper office while a night edition was being prepared for the presses. Men of this type have endured all sorts of hardship and they calmly accepted conditions, no matter what they were. The woman on board was very courageous and showed no fear. We saw very little of the crew, as all of its members were busy.

The treacherous "mistral" wind prevalent over the southern coast of France results from the heated air
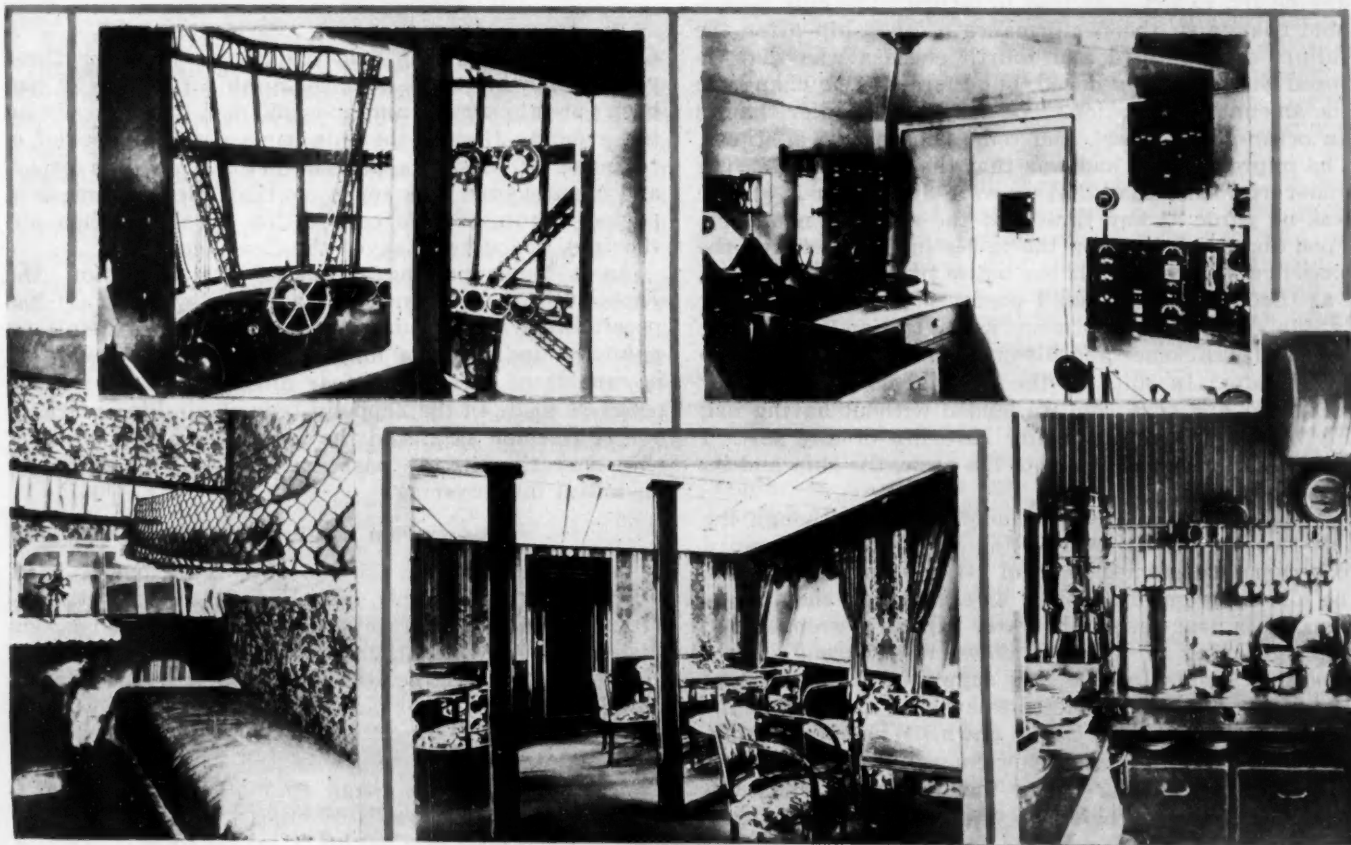
VARIOUS OPERATING AND PASSENGER COMPARTMENTS ON THE GRAF ZEPPELIN

Fig. 3—Control Compartment   Fig 4—Wireless Telegraphy Room and Equipment

Fig. 5—A Stateroom with Upper and Lower Berths, the Lower One Transformed into a Couch   Fig. 6—Dining and Recreation Salon, Extending the Full Width of the Airship, with Windows on Either Side   Fig. 7—Galley, Showing Electric Stove Supplied with Current from a Propeller-Driven Generator
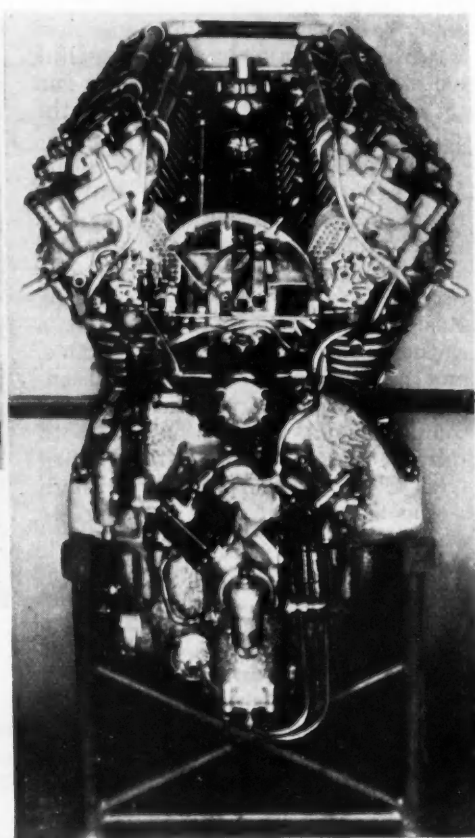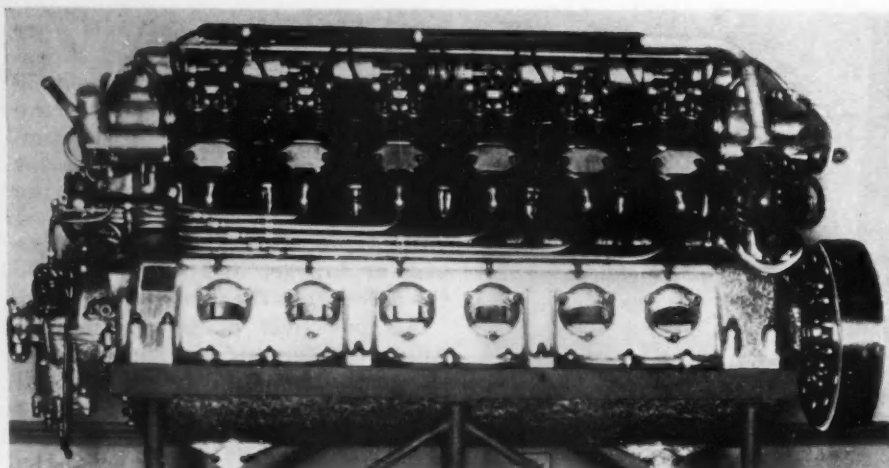
FIG. 8—SIDE AND END ELEVATIONS OF THE 12-CYLINDER, 550-HP. MAYBACH-
ZEPPELIN VL-2 GRAF ZEPPELIN ENGINE

This Engine Is Directly Reversible and Can Operate on Either Liquid or Gaseous
Fuel. It Represents the Most Advanced Type of Internal-Combustion Engine Yet
Constructed

of the Sahara Desert which passes over the Mediter-
ranean Sea and is thus cooled. This wind is stratified
and blows at different speeds at different elevations; it
is very strong and erratic, blowing in gusts.

We had no intimation that the first and second en-
gines had failed, but after the failure of the second
engine Dr. Eckener decided to return. The only notice-
able change in the performance of the ship after the
failure of the third and fourth engines was that its
speed was slightly reduced, but there was no change in
the amount of vibration. The ship was steadier than is
an ocean-going vessel, and rode smoothly at all times.
The impression we had was that the earth was passing
under us, rather than that we were flying over it. There
was no panic at any time, and the ship did not lurch.
Food and drink were on the tables in the salon and the
passengers ate as usual; one bottle tipped over, but that
was the only disturbance I observed. I happened to be
in the control compartment when the engine trouble
began. Dr. Eckener and his crew were at all times per-
fectly calm. In spite of the trouble, no great danger
existed at any time, and we landed without having had
any one injured or enduring hardship of any sort. I
think this is a great credit to the crew, the ship and its
capability.

About 12 attempts were made to land; although the
first two or three were exciting, we seemed afterward
to become accustomed to them. In descending to earth,
the elevating gas is allowed to escape and then, when
the ship is near the earth, water ballast is dropped and
this lightening of the ship allows it to ascend. After
several attempts to land, the supply of ballast and of
lifting gas had been depleted to such an extent that the
ship was unable to go up or down. When we last as-
cended, we could see the snow-capped Pyrenees Moun-
tains and were being blown toward them. Then the
wind changed and blew us toward the only hangar
available.

It was nearly dark when we approached the landing-
field at Cuers, but the beacon was lighted and operating,
which indicated that the French authorities had re-
ceived the notification Dr. Eckener had sent about 2 hr.
previously announcing his intention of landing at

Cuers. Although this field had been closed for three
years, following the loss of the airship Dixmude, it had
been put into service and about 50 men were already on
the ground. Just as the ship came near the ground, a
regiment of troops appeared and the soldiers seized
and manipulated the ropes so that the ship made a
perfect landing. This cooperation by the French au-
thorities undoubtedly saved the Graf Zeppelin.

As a money-making means of transportation, the
Zeppelin type of aircraft has a long way to go. It has
possibilities for unusually long trips and for attaining
publicity and, from a military viewpoint, it certainly
is capable of awakening fear among the enemy. The
progress made in the Zeppelin type of airship is largely
due to German skill, and the fatalities in Zeppelin-air-
ship operation in the past may have been caused by
unskillful maneuvering.

Description of the Engines

The five 12-cylinder, 550-hp. Maybach-Zeppelin VL-2
engines of the dirigible (see Fig. 8) are directly re-
versible and can operate on either liquid or gaseous
fuel. They represent the most advanced type of inter-
nal-combustion engine yet constructed. Mounted in
individual power-gondolas, as shown in Fig. 9, and
slung beneath the great hull in a staggered position
such that the propellers are not affected by the back-
wash of the propellers ahead, they afford the airship a
cruising radius of about 6100 miles. Each weighs 2450
lb., and their total of 2750 hp. gives the ship a cruising
speed of about 72 m.p.h. in still air and a top speed of
80 m.p.h. The VL-2 type represents a development of
the Maybach-Zeppelin engines built in Germany in 1924
for the United States Navy airship Los Angeles. That
type produced 420 hp. at sea level and 400 hp. at the

altitude of Friedrichshafen, Germany, at 1400 r.p.m.; but the VL-2 type develops 600 hp. at sea level and 550 hp. at Friedrichshafen, at 1600 r.p.m., on account of increased compression, carbureter alterations and the use of aluminum pistons.

Whereas light weight per horsepower is the primary consideration for an airplane engine, fuel economy and reliability are the prime requisites for the engines of an airship. On long cruises, an airship runs for perhaps as long as 100 hr. without stopping and, if it can save a quantity of fuel while producing a given horsepower, the reduction in the total amount of fuel that must be carried will more than offset the greater weight of the engines. Most airplane engines require overhauling after about each 200 hr. of operation; but, if that were true of an airship engine, it would necessitate complete overhauling after crossing the Atlantic twice, and this would mean either a long lay-off for the ship at the end of each round trip or require the provision of two sets of engines, one to replace the other. Tests at Friedrichshafen indicate that the VL-2 type will need minor adjustments only once each 1000 hr., and that major overhauls will be necessary only once each 2000 hr. This advantage is largely attributable to the exclusive use of the new Maybach roller-bearings used virtually throughout the engine. Except for the piston-pin bushings, all rotating surfaces, including the crankshaft ends of the connecting-rods, float on these anti-friction roller-bearings.

Direct Reversibility a Feature

Reversing gears have been eliminated in the VL-2 type engine; a simple shifting of the camshaft changes the timing of the 36 overhead valves, thus enabling the engine to run in a clockwise or counter-clockwise direction, and this is the only readjustment entailed in reversal. A compressed-air starter cranks the engine in either direction, and its reliability is substantially infallible. An airship is handled much like a steamship and, to moor to a mast or to land, the engines must at times be reversed to drive the ship astern as a steamship is maneuvered when about to dock. This was formerly accomplished by utilizing reversing gears between the engine and the propeller, but the gears added to the weight of the engine, necessitated longer and heavier power-gondolas and caused frequent trouble. In maneuvering the airship, by running the port engines ahead and the starboard engines in re-
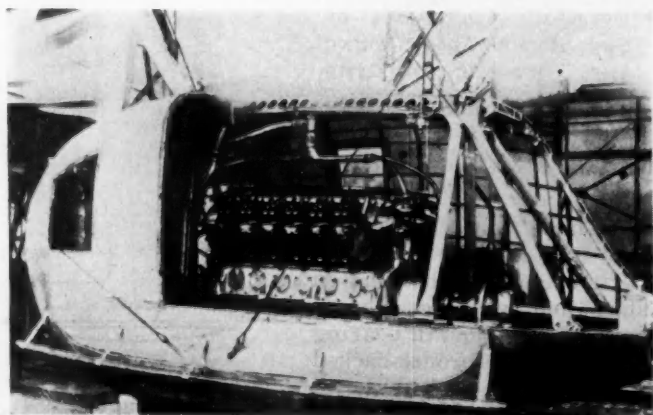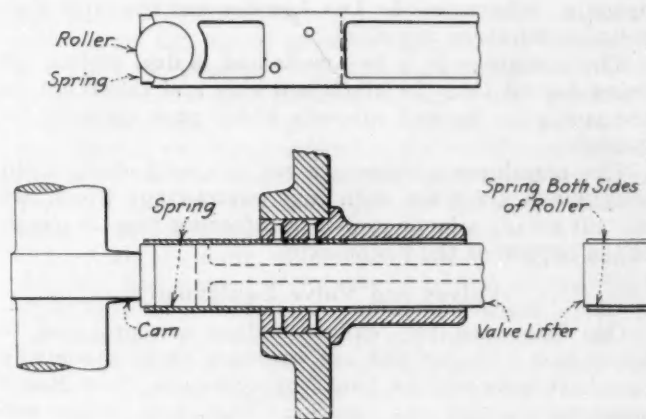

FIG. 10—SKETCH OF THE VALVE-LIFTER CONSTRUCTION

verse, or the port engines in reverse and the starboard engines ahead, the ship can be turned around.

Reversal of the engine is accomplished by moving the camshaft either forward or aft, this slipping of the camshaft being a light mechanical arrangement for accomplishing reversal without the use of heavy gears and gearboxes. A two-cylinder two-stage air-compressor mounted on the end of the crankshaft furnishes compressed air to the engine starter at a pressure of 450 lb. per sq. in. In the first stage of compression, a mechanical inlet-valve is operated, and in the second stage an automatic valve operates. Between the first or low-stage cylinder and the larger-stage cylinder is an air intercooler in which the air is cooled by oil. This small two-stage air-compressor has given no trouble on any of the engines in the Los Angeles airship and apparently is very satisfactory. The engine speed is normally 1600 r.p.m.

The 12 individual cylinders of this V-type Graf Zeppelin engine are of cast iron and have a steel water-jacket welded to the top of each cylinder. At the lower end the outer steel shell of the water-jacket fits into a bronze ring which bolts through the lower flange of the cylinders and to the crankcase, constituting an expansion joint. The steel sleeve expands less than does the cast iron and the joint is made tight by using a gasket or a ring of rubber packing.

The improvement in the engines of the Graf Zeppelin as compared with those of the Los Angeles, the best engine of which has run for 800 hr., consists in the raising of the compression ratio from 6:1 to 7:1, using "blau gas" instead of gasoline, and lightening the valve mechanism somewhat. In the tests, the Graf Zeppelin engines were run-in 400 hr. on the brake; 300 hr. on gasoline, and 100 hr. on blau gas.

The carbureters are of the Maybach three-point adjustable type; that is, an adjustment is provided for the throttle and for the venturi, and a cam is filed so that the needle-valve is raised and lowered in proportion to the variable flow through the throttle and the venturi. In other words, when the engines are being run-in and the exhaust-gas flame is watched, the cam is filed for each notch in the throttle opening. In this manner each bank of three cylinders is adjusted by filing the cam so that the explosions in the three cylinders are equal. The carbureters on the Los Angeles engines are being refitted by installing a small gas manifold which introduces the blau gas at the throttle

FIG. 9—POWER GONDOLA OF THE GRAF ZEPPELIN, SHOWING THE MANNER IN WHICH THE ENGINES ARE MOUNTED

opening; otherwise, the Los Angeles and the Graf Zeppelin carbureters are alike.

The crankcase is in two parts and is dry, cooling air being forced into the starboard side and taken out on the port side through airports which pass through the gondolas.

The aluminum pistons are not of particularly light weight and are fitted with four piston-rings which are not cut away; a large cast-in reinforcing ring is placed at the bottom of the piston skirt.

Valves and Valve Equipment

One inlet and two exhaust-valves are provided to serve each cylinder and are operated from a common camshaft between the banks of cylinders. Two Bosch magnetos provide the ignition. The valve lifters are located between the cylinders in three small banks mounted on aluminum to compensate for expansion. As shown in Fig. 10, the valve lifters are rollers, each mounted at the end of a stem. The fact that no pins are used for the rollers is perhaps one of the best features of their construction, which is certainly neat and attractive. The roller, which is similar to that in a Hoffman bearing, is of case-hardened steel and fits into a steel-forged guide milled out so as to be light. It is held in place by the end of the lifter, which partly surrounds the roller; that is, a hole is bored in the end of the lifter, the roller is inserted, and then that part of the guide which would form the lower part of the retaining ring around the roller is cut away. The guide is held in its lifter by side flaps of steel so that the lower roller can spring back and forth as the camshaft is moved forward and aft to reverse the engine.

The valve-lifter rods are hollow and filled with oil. Ball-shaped cups are formed at the ends. The springs are actuated by adjustable valve-lifter contact-pushers; that is, as indicated in Fig. 11, as the valve lifter hits the top of the valve, the inaccuracy caused by the angularity of the rocker itself is corrected by a ball-shaped self-adusting contact-pin.

Referring to the fore-and-aft movement of the camshaft for engine reversal, this is accomplished by a mechanism which consists of a gear with a shank on it which is splined and case-hardened. This is in turn fitted into a bronze sleeve which has ordinary splines on the inside and spiral splines on the outside. The bronze sleeve carries an outer sleeve having internal spiral splines that engage the bevel-gear drive of the camshaft. These parts are all machined, ground, hand-fitted and lapped, and any two splines are interchangeable. No backlash exists between the straight and the spiral sets of splines, and this mechanism, which weighs perhaps 10 lb., is as fine a piece of hand craftsmanship as I have ever seen. This work could not have been done by machine-tools alone; it must represent at least two months of hand work by the best tool-maker one can imagine.

The counterweights on the crankshafts are V-shaped at the bottom and bolted into place with U-bolts. Great difficulty was experienced in holding the counterweights in place. It was found that the crankshaft torsional vibrations loosened the counterweights, and the U-bolts were then made heavier; but it was finally found after using lighter U-bolts that these were more satisfactory than the heavier bolts because the smaller shank gave them more flexibility and allowed them to stretch.

As indicated in Fig. 12, the steel flywheel is in two thin parts, the inner part carrying the propeller and the outer part being bolted to the crankshaft. The outer portion has fins on the inside, each of which carries a set of four small spiral springs. The springs are about 1 in. in diameter and 3 in. long and have a steel plate at each end. The spring ends are tied together by a small strip of metal inside the spring. The outer portion of the flywheel is equipped with about 20 sets of these springs, which are between the inner rib of the outer portion and the outer rib of the inner portion of the flywheel. The springs tend to take up the crankshaft torsional vibration and smooth out the roughness of operation caused by the propeller; in fact, they act as torsional dampeners in a manner similar to that of the Lanchester dampener, compensating for the difference between the inertia of the flywheel and that of the crankshaft, and discounting the effect of the inaccuracy of balance of the crankshaft so as to minimize the dynamic loads caused by the out-of-balance condition.

A large main roller-bearing is located between each two pairs of cylinders. The crankshaft turns on seven of these main roller-bearings and on a combined main and thrust bearing. Lubrication is by spray under pressure from an oil-pump. Two scavenging oil-pumps are used and are mounted at either end of the crankcase so that the oil drainage can be caught at whatever angle the ship may tilt.

A rubber joint is provided to compensate for the expansion between the aluminum manifolds. Two manifolds are provided for each bank of six cylinders, there being one manifold for each carbureter. At about the center of the manifold on either side is a small orifice by means of which proper balance is maintained in case one set of three cylinders is not in step with the next set of three cylinders. These manifolds are machined on the inside to facilitate the flow of gas.

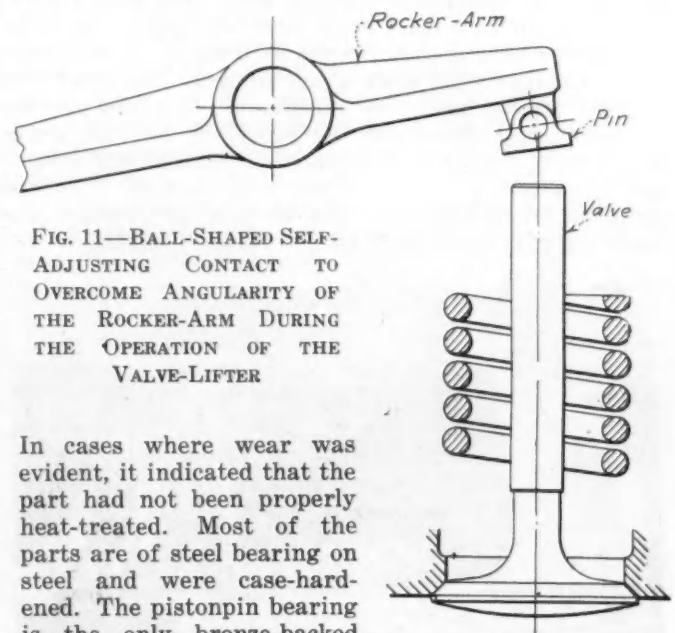The materials used all seem to be of the best quality.

FIG. 11—BALL-SHAPED SELF-ADJUSTING CONTACT TO OVERCOME ANGULARITY OF THE ROCKER-ARM DURING THE OPERATION OF THE VALVE-LIFTER

In cases where wear was evident, it indicated that the part had not been properly heat-treated. Most of the parts are of steel bearing on steel and were case-hardened. The pistonpin bearing is the only bronze-backed bearing in the main drive. The length of the connecting-rod is about 2.4 times the length of stroke, and the lower end or ring must be say 10 in. in diameter. A large roller-bearing is carried

at the lower end and the rods themselves are thin steel forgings. The upper end has a bronze bushing about ⅜ in. thick and an oil groove in the form of a double-eight.
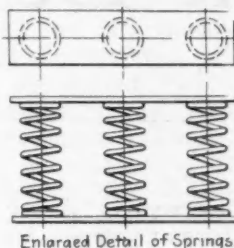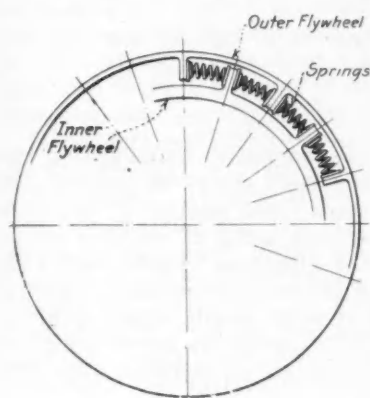

FIG. 12—SKETCH SHOW-ING THE RELATIONS OF THE OUTER AND THE IN-NER STEEL FLYWHEELS

The pistonpin is of steel. It is held in the piston by being tapered on one end and floats on the other end, the bolt through the hollow pin holding the pin into the taper. That this is not a practical design is indicated by the fact that this assembly has come loose and has scored the cylinders, it being the only feature that is not pleasing in the design. The timing gears are of steel and are case-hardened.

Advantages of Two-Fuel System

The advantages obtained by adapting the VL-2 engines to the use of either gasoline or blau gas are very great and perhaps this is the most significant feature in the advance of the development of lighter-than-air craft. The carrying of gaseous fuel is dependent only upon the space available, and weight is a negligible factor. As the head resistance of streamlined airships does not increase in the same ratio with their size, an appreciable lengthening of cruising radius can be effected by the use of gaseous fuel since it imposes no excessive strain upon the framework of the ship, which must be made considerably stronger and heavier if large quantities of liquid fuel are to be carried. In the case of the Graf Zeppelin, its duralumin skeleton has been made stronger than has the framework of any previous airship, and therefore the use of gaseous fuel affords an additional margin of safety.

Instead of using water as ballast which can be dripped and wasted if buoyancy is lost during flight, eight tons of gasoline are carried and, when it becomes necessary to lighten the ship, gasoline is used as fuel until the weight of the supply has been reduced sufficiently to afford the desired extra buoyancy.

The VL-2 engines were adapted to the use of gaseous fuel by hollowing the throttle valves of the fireproof Maybach carbureters. Pipes lead into these valve shafts from the bags which contain the blau gas, and an adjustment valve controls the flow of gas according to the position of the throttle. Another valve, inserted in the gas feed-lines, permits a change from gaseous to liquid fuel, or vice versa, in a few seconds without interrupting the operation of the engine or impairing its power output.

Blau gas was developed as the result of extensive experiments resulting in the compounding of a number of gases. Its weight was intentionally made somewhat heavier than that of air so that it will drain by force of gravity from the storage bags into the carbureters and so that its consumption will lighten the ship slightly and counteract an equally slight loss of buoyancy caused by the inevitable seepage of the hydrogen or the helium used as lifting gas. The liquid-fuel consumption of the engines at full load averages 0.451 lb. per hp-hr., as compared with 0.551 lb. per hp-hr. for the ordinary aviation engine. In other words, each engine uses 270 lb. or about 38.5 gal. of gasoline per hour to develop 600 hp. at sea level.
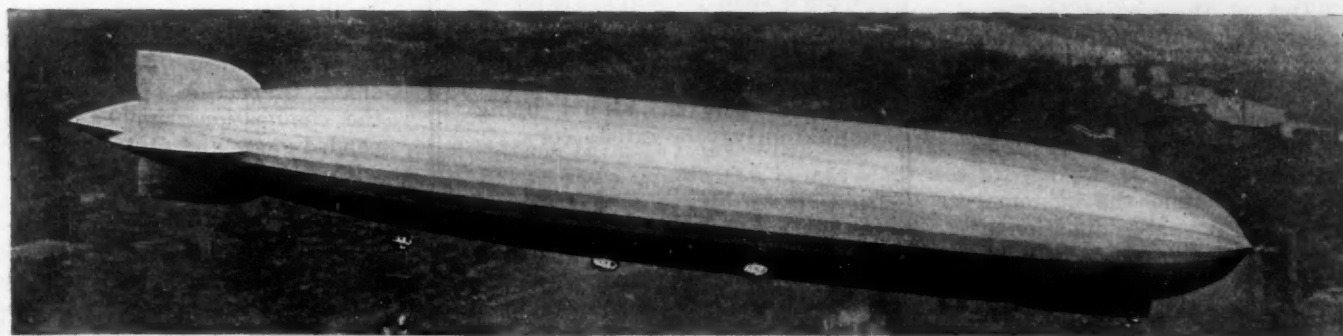
Outboard Engine Development

By J. E. WILKINSON[1]

WHEN we speak or think of an outboard engine today, it immediately brings to mind power and speed on the water and spills for the race driver, who never misses the thrills that are many and varied in outboard racing. But in ordinary service there is little danger; even the necessity of having to row back to camp is rare with present-day outboard engines.

Until a few years ago an outboard engine was thought of as a "putt-putt" or "mud-churner" to be fastened to the stern of a rowboat so that, when tired of rowing, one could expect to make a quick trip to where the fish bite; but, after his hand became so blistered from trying to start the engine that he could not hold an oar, one hoped the wind would change so that he would drift back in time for supper. Today, the situation is quite different; if the engine does not start, this means that you have forgotten to read the manufacturer's book of instructions.

The following is a definition of an outboard engine as given by the American Power Boat Association for 1929:

An outboard motor is a complete internal-combustion power-and-propulsion unit attached to the boat, which can be lifted by human power from the hull as one unit, excepting battery for ignition and starting, tachometer, steering and throttle control arrangements.

One of the earliest outboard engines was built in 1897. About the year 1900, various engineers were thinking of a detachable boat-engine, and about 1910, outboard engines were presented to the public.

At that time the customary inboard internal-combustion engine used for power in a boat was of the two-cycle type. It was natural for the outboard engine to follow the same general construction. Almost the first practical outboard engine was a single-cylinder two-cycle type of 2½-in. bore by 2½-in. stroke, which developed approximately 1½ hp. at 900 r.p.m. and weighed about 55 lb. Other companies saw the possibility of doing a successful business with such engines, and at one time possibly 20 or 30 concerns were manufacturing them.

Soon a demand arose for more power and, if possible,

After a definition of the outboard engine is given, the history of this form of power-and-propulsion unit is reviewed and its development from the earliest types traced. Outboard engines are preponderantly of two-cycle design, with top-speeds of present-day units well above the maximum speeds common in motor-car engines.

The a u t h o r describes the means of carburetion, lubrication and ignition used in outboard engines. The desirability of special spark-plugs designed to withstand the intense heat created in fast outboard engines is emphasized, as is also the importance of constructing flywheels with an ample factor of safety.

In the discussion the question of underwater exhaust is considered, this m e t h o d being apparently very satisfactory.

less weight. Power was first increased by enlarging the bore and stroke, but as this could not go on indefinitely, the next development was a light engine of opposed-cylinder design. Simultaneous firing of opposed cylinders markedly reduced the vibration experienced with the single cylinder. Then the outboard-engine industry rapidly became very active, and a small, single-cylinder engine weighing about 26 lb. made its appearance, as did also a two-cylinder model which weighed about 35 lb. and developed 2½ hp.

Soon the outboard engine entered the racing field and events began to happen in earnest. In the typical early race, all contestants were required to tie their boats to suitable objects, preferably a bridge, and then to start their engines. When everybody was ready and the starting-gun fired, each rope was cut. Racing speed was 8 to 12 m.p.h., which was previously unheard of and never expected of a "putt-putt."

Manufacturers now sought for increased horsepower, and each company worked on its own ideas of construction. I dare say that to some the thought of a two-cycle engine brings back memories of cranking, in either a boat or an automobile; however, the absence of valves and camshaft simplifies construction. The need of valves is eliminated by using the piston to open and close a series of properly spaced ports in the cylinder. In the two-cycle engine there is a power stroke per cylinder at every revolution of the crankshaft, the action of scavenging the combustion-chamber of expended gases and replacing them with a fresh charge occurring in a very small fraction of a second. The inlet port is uncovered by the downward travel of the piston and the incoming gas is deflected at the most suitable angle by a baffle-plate, which is a raised section at the piston-head, so that as much as possible of the fresh charge can be utilized. Although the incoming gas enters the combustion-chamber at the same time that the burned gases are being expelled, the exhaust port opens a short time before the inlet port.

Carburetion and Cylinder Charging

Carbureters used with such engines are somewhat different than those for four-cycle practice. So far, a

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float for keeping the gasoline supply constant in the float chamber and a jet with a needle-valve located in the air-intake to govern the quantity of gasoline feeding through the jet seems to be as efficient an arrangement as any. Proper adjustment of the fuel-feed depends upon the engine speed. No adjustment wholly suitable at all engine speeds has been found. I have tried possibly a dozen jets of different shapes and sizes, with the same results in revolutions per minute.

Manufacturers differ regarding the best way of conveying the mixture from the carbureter to the combustion-chamber. In all cases the charge is first taken into the engine base. One maker uses a simple check-valve which opens when both pistons are traveling upward so that the charge is taken in gradually; the instant the pistons start to travel back, the valve closes automatically and the gas is compressed in the base. The compressed charge then passes through a transfer port from the base into the combustion-chamber when the piston-head uncovers this port. This design is commonly known as a two-port engine.

Another type does not take a charge into the base until a partial vacuum is created there. In this design a third port, sometimes called the intake port, is controlled by the skirt of the piston and is not open as long as is the check-valve type, but the incoming gases have more velocity. The charge is transferred to the combustion-chamber in the usual way. Still another design, which is a new development this year, uses a rotary valve. This tends to give uniform operation but, as gears are used in it, the system is somewhat more complicated than the others.

Methods of Lubrication

For lubrication, oil is mixed with the gasoline in quantities depending upon the engine speeds. In ordinary service work about 1 pt. of oil to 1 gal. of gasoline is sufficient, but when engines are used for racing the usual mixture is 1 qt. of oil to 1 gal. of gasoline. In some cases, additional pure oil is fed through the air intake.

A few years ago many engineers thought that a two-cycle engine could never be run faster than 2500 r.p.m. Today, engine speeds vary from 4000 to 6000 r.p.m.; consequently, lubrication is very important, as with increasing engine-speed and horsepower more friction and stresses must be overcome. Roller and ball-bearings are used in most cases.

This year one engine has a drilled crankshaft. The method of feeding pure oil by gravity rather than by pressure system seems to be preferred. One oil-feed pipe delivers oil to the top main bearing, then through the shaft to the end of the top crank-throw. Here the oil is thrown out through an opening in the bottom half of the crankpin bearing, the centrifugal action of the crank being utilized in addition to gravity feed. The oil thrown from the crank lubricates the opposite cylinder-wall and piston-pin.

The bottom main and crankpin bearings are lubricated in the same way by another gravity-feed pipe. The greatest amount of friction in the power-head is found to be at the crankpin bearings. Tests show, it is claimed, that with this system of lubrication, when the engine is driven by an outside source and one cylinder is removed, oil will spray 10 ft. away from the base, and that 75 per cent of the original oil in the feed-cup can be reclaimed. Plain metal bearings are used in this engine. Some other engines use roller-bearings to reduce friction on the crankpins and, for lubrication, employ the usual method of mixing oil in the gasoline.

Flywheel Magneto and Special Spark-Plugs

Ignition commonly involves the use of a magneto built into the flywheel. Spark-plugs are a very important detail. I remember playing one day with an engine which turned about 3800 r.p.m. with the muffler on; when the cut-out was opened the speed would rise to 4000 r.p.m. After the boat had travelled about 200 ft., the engine would stop completely. Then it would start immediately and I would try to cut-out again, with the same result. At first I thought the trouble was due to too slow a gasoline supply and watched the float level when the engine stopped, but plenty of gasoline was always in the chamber. Finally I changed to different spark-plugs, and then the engine would run all day at 4000 r.p.m. It was my first experience with a simple case of pre-ignition.

At the races, representatives of spark-plug manufacturers came to offer us the fastest spark-plug ever made. When we expressed belief that some new type of plugs should be developed for outboard engines, they smiled and told us that we did not know what it was all about. However, about a year later the manufacturers went to work and asked for the assistance of the outboard racing drivers to help in the experiments.

A two-cylinder engine of 19-cu. in. displacement developing about 14 hp. at 5000 r.p.m., for example, surely needs a cold plug to withstand all the heat developed. Engine manufacturers are now looking for a piston metal that will withstand the terrific heat generated at the piston-head. Some trouble has been experienced this year from holes being burned through the piston-head. I have seen pistons with holes as big as a dime or a quarter, and sometimes the aluminum ran out of the exhaust port.

Among the questions I have been asked was the speed at which the flywheel would burst and what would happen when it did. To gain this information by experiment, a safe place was selected; a box was constructed of wood, using sides 4 in. thick and surrounded by several tons of coal; a flywheel made of aluminum alloy was placed in the center, and a suitable method was used to indicate the r.p.m. of the flywheel. At 9000 r.p.m. it ran very smoothly; at about 12,000 r.p.m. the flywheel could be seen, from a platform above, to grow larger. Next, there came a loud report, like that of a gun, when the flywheel broke into pieces of all sizes and shapes. Most of the pieces were never found; some penetrated the 4-in. sides of the box and were lost in the coal. I hope that manufacturers will always construct their flywheels with a high factor of safety.

The lower unit of the engine, that is, the part below the powerhead. which contains the driveshaft and the

underwater housing with the necessary propeller-shaft and propeller, also affords an interesting study. In the design for ordinary service the shape and balance of the underwater housing are almost negligible. At very high boat-speeds, however, the action is vastly different. I remember a very peculiar case which so far remains unsolved. It happened with a boat weighing about 75 lb. and an engine weighing 69 lb., with everything adjusted for maximum efficiency. The boat, when travelling its fastest on a straight course, would turn end for end for no apparent reason. This happens occasionally if some floating object is struck, but when the water is clear the occurrence is difficult to explain. If a piece of paper no larger than a post-card happens to find the right spot on the gear-housing below the water, an upset is the usual result.

With some engines and boats, the greatest speed is obtained by having the engine fastened to the stern so that as little as possible of the gear-housing is in the water, thus reducing the drag. If one could visualize a boat weighing 75 lb. travelling 38 to 40 m.p.h. with nothing protruding below the bottom of the hull, he would know that to keep it in a straight line would be difficult. This offers a partial explanation, I believe, of the behavior when the boat is up to full speed with as much of the gear-housing as possible out of the water.

THE DISCUSSION

W. M. CLARK[2]:—In some of the recent craft built, not for speed but for fishing and family use, some designs have the engine enclosed and located on a sort of forward bulkhead. This design arouses two questions in my mind, one as to ventilation of the engine as regards the cooling and stifling from the exhaust, and the other as to the resistance set up by the well. Are these important factors?

JACOB DUNNELL[3]:—Fumes have been very bad in the past. Most of the new engines coming out this year are of the underwater-exhaust type. The only trouble they have shown is with ventilation and it is not caused by getting air into the water. As to drag of the well, I do not think any difficulty will be experienced; the water immediately behind the propeller is so broken up in the slipstream that it has little effect on the bottom at that point.

G. S. WHITHAM[4]:—At what expense in power is the underwater exhaust obtained?

J. E. WILKINSON:—That works out differently with different makes of engines. Some horsepower is lost by using some underwater exhaust methods. At the Miami races last March I used an engine having an underwater exhaust. After making a fast drive, I took off the muffler and tried the engine with open exhaust. The speed dropped 200 r.p.m., which proved that this particular make of engine was more efficient when exhausting under water. At a boat speed of less than 20 m.p.h. there is back-pressure, but above that speed the underwater exhaust seems to help. It is important that everything be sealed; a little air-leak will cause a drop in engine speed of perhaps 75 r.p.m.

PROF. DEAN ABNER FALES[5]:—If you want to go fishing in an ordinary boat that makes 14 m.p.h., what do you do with the engine when you want to troll at the fishing place?

MR. WILKINSON:—A fishing boat is small and, in my opinion, an engine weighing about 25 lb. is the proper size. Furthermore, by means of a patented arrangement which fastens to the cantation plate, the speed of the boat can be controlled for trolling and the engine can still run at fairly fast speed. Thus the boat speed can be adjusted to about 2 to 4 m.p.h. without worrying about stalling the engine.

JOHN F. DUBY[6]:—What is the gasoline consumption per horsepower developed in these two-cycle engines as compared with automobile engines?

MR. WILKINSON:—I should say roughly about five times more gasoline per cubic inch of displacement. The two-cycle engine is very inefficient. If we could get the two-cycle engine up to the efficiency of a four-cycle engine, as far as gasoline consumption is concerned, and fire nearer dead center, we would obtain much more horsepower.

[2] M.S.A.E.—Superintendent of transportation equipment, S. S. Pierce Co., Boston.

[3] Naval architect and chief engineer, Eastern Service Marine Co., Boston.

[4] M.S.A.E.—Managing director, Charles Street Garage Co., Boston.

[5] M.S.A.E.—Associate professor, automotive engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[6] M.S.A.E.—Proprietor, J. F. Duby Co., Dorchester, Mass.

Combustion-Chamber Design in Theory and Practice

By W. A. WHATMOUGH[1]

POINTING out the difference between scientific and industrial progress as manifested by heat theory and engine design and the Carnot and Otto cycles, the author discusses the working principles of combustion. A simple synopsis of internal combustion is presented, followed by a discussion of influence of spark-plug location on detonation and pressure rise and some observations on overcooling and flame quenching.

The reasons underlying the decision to use a particular type of engine in an automobile are commented on, and this is followed by a discussion of the limitations imposed upon induction and combustion by such a choice. The advance in combustion-chamber design is traced from the early T-head through the L-head, in various forms, the overhead-valve, the hemispherical and four-valve types. Drawings of the different heads supplement the text and some comparative power curves are included.

New developments receive some consideration and a statement of the Whatmough principles of combustion control is given. The coordinated application of the heating, flow and cooling effects to engine design is discussed at some length and a combustion-chamber head requiring mixture control and compensatory water circulation is illustrated. This design uses a curved venturiform annulus for the inlet port to deflect the gas-flow into the cylinder and lessen the effect of varying suction during sudden opening and closing of the valve and differential water circulation with two separate outlets controlled by thermostats to assure smooth burning and fuel efficiency by preventing overheating and overcooling.

Compactness, turbulence and central spark-plug location are postulates from heat theory which have become traditions in combustion-chamber design. The conflict between theory and practice in these respects is discussed, with reasons given for the failure of the former and the success of the latter. The relative importance of the factors of service, economy, power, smoothness and flexibility in commercial vehicles and high-grade passenger-cars is stated and their dependence upon combustion control is emphasized.

HEAT theory and engine practice bring out an all-important difference between scientific and industrial progress. Industry lives and grows by achieving positive results and selling them at a profit. Science in its search for knowledge pays little heed to limitations of time, or thought, or treasure.

The production of automobiles has become the world's greatest industry by making engines that work better in practice than could be expected upon theory. Indeed, production and development departments are separated in engine manufacturing because advances in engine design based upon scientific research are likely to prove costly in service and detrimental to sales unless the improvements have stood the test of time.

The Failure of Heat Theory

Conventional science guides the designer of internal-combustion engines to a surprisingly small extent. This can be a consequence only of the adoption in thermodynamics of mathematical concepts that have no practical equivalent in combustion. Physics, which is virtually applied mathematics, utilizes and even *mixes* the totally distinct gas kinetics and thermodynamics in its calorific calculations and then transposes calories into the ergs of the diametrically opposed electromagnetic and quantum theories.

The mathematical expression involving heat equivalents fits each theory, as shown elsewhere[2], but the interpretation varies according to the theory involved and results are given in terms of whatever heat units are arbitrarily chosen. Finally, statistical averaging destroys that temporal and spatial picturization of heat development and energy transference[3] that is necessary for the understanding of power production in an internal-combustion engine. Imaginary laws of motion are the result of abstract philosophy and, though mathematical metaphysics are an advance on medieval mysticism and primitive magic, the future of science in general and of heat engines in particular centers in real working principles.

Thermodynamics awards the prize for engine efficiency to the Carnot cycle represented by the hot-air engine. This heat theory has evolved a principle of maximum work which in effect must also be a principle of no work, since to secure maximum theoretical efficiency an infinitely great time has to be taken in working the cycle to avoid heat loss by friction. This objection is typical of the way in which heat theories contravene actuality by ignoring time limitations or by disregarding the linked interaction of space and matter.

The Otto-cycle engine has been proved the most practicable for road transport despite heat theory making it supposedly inferior in efficiency owing to the irreversible nature of its operation. As a matter of fact, internal-combustion engines derive their motive power from chemical reactions that must be *non*-reversible during the operative portion of the cycle, as this is the only

[1] F.M.S.A.E.—Consulting engineer, Automotive Engineering Co., Ltd., Twickenham, England.
[2] See *The Automobile Engineer*, September, 1927, p. 346.
[3] See *The Automobile Engineer*, August, 1927, p. 306.

means of getting work out of this type of prime mover, wherein the rate of heat generation controls the impulse characteristic of the working stroke. The flexibility and practical advantage of the gasoline engine are bound up with the success attained in regulating this heat generation to suit a wide range of engine speed.

Working Principles of Combustion

My criticisms of heat theory have hitherto been incidental to a detailed discussion of the problem of engine knock[4]. During the comprehensive review in question, thermal exchanges between the burning mixture and its enclosure, including unburnt combustible, were shown to control flame speed and pressure rise. It was discovered that temperature and pressure combine into a mobile or dynamic physico-chemical equilibrium. Instead of heat being continuously degraded to a degenerate state, the contents of any enclosure are continually receiving and exchanging energy. The articles in question conclude with a compendium of terms, in both simple and scientific language[5], explaining combustion as met with in engine practice.

The mechanics of combustion simplifies into a rise and fall in working pressure due to an enormous succession of momentary phases of emission of radiant, or heat, energy. A series of snapshots of flame travel[6] traces the path of inflammation as instantaneous states of incandescence. Automobile engineers who have difficulty in following the descriptions of flame propagation should remember that my task was the unenviable one of portraying a motion picture of a strange technology,

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[4] See *The Automobile Engineer*, February, 1927, p. 55.
[5] See *The Automobile Engineer*, December, 1927, p. 502.
[6] See *The Automobile Engineer*, June, 1927, p. 207.
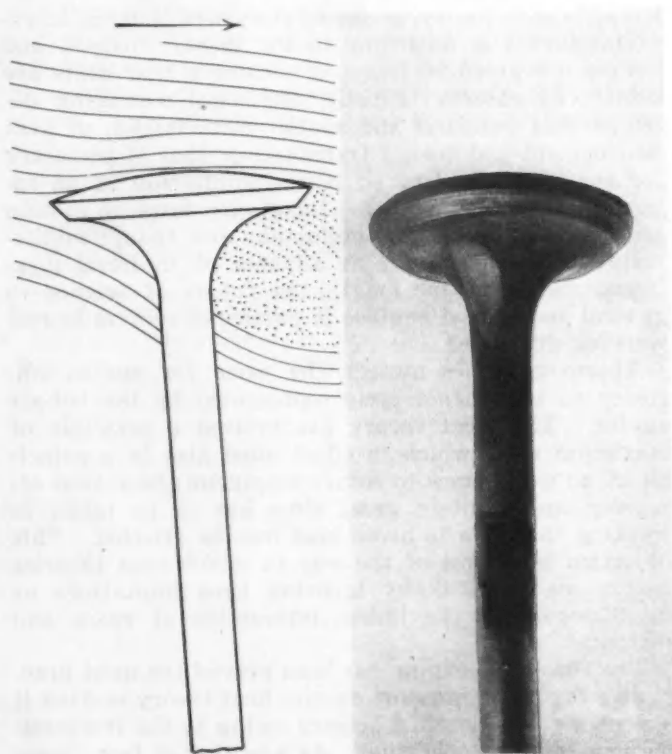
FIG. 1—THE SWEPT EXHAUST-VALVE
(Left) A Diagrammatic Idealization Made in 1927 and (Right) Photograph Taken in 1929, Showing Eddy Marking by Flame

with ultra-scientific titles, by stationary photographs and simple language. A clear understanding of the sequence of events leading to the smoothing of engine torque is the prime need in combustion-chamber design. Incidentally, torque is one of the few words including coupled action in its meaning.

The connection between piston movement and the pressure rise synchronizing with flame travel should be readily visualized from the following simple synopsis of internal combustion:

(1) *Heat* is generated by burning air carbureted with hydrocarbon vapor, the evolution of energy occurring during the chemical reunion of atoms

(2) *Flame* travels just as fast as energy becomes available to fire fresh charge

(3) *The flame front* is a surface extension of inflammation during normal combustion

(4) *Spontaneous combustion*, or auto-ignition, is due to combustible becoming heated throughout its volume to its self-ignition point

(5) *The flame thrust* is smooth or uneven or rough according to the timing of the rate of inflammation

(6) *The working parts* are stressed in accordance with flame speed

(7) *Regulated burning* is characterized by steady or steam-like propulsion

(8) *Shock loading* of piston and rough running result from unduly rapid pressure-rise

(9) *Engine knock* is reaction to high-speed projection of flame, due to auto-ignition subsequent to spark ignition

(10) *Heating* combustible increases flame speed

(11) *Cooling* compressed charge slows flame travel

(12) *Overheating part of combustible* during compression by flame front may lead to engine knock

(13) *Overheating prior to sparking* causes pre-ignition

(14) *Overcooling* leads to (*a*) fuel deposition during compression, (*b*) failure to fire and (*c*) quenching of flame after firing

Inversion of a theoretical cycle into a working cycle adequately summarizes what has been already mentioned in this and other previous papers. Results obtained by applying the foregoing principles to engine construction bear out their practical utility.

Interpretation and Misinterpretation

Correct interpretation of effects due to changes in detail design are vital to real progress in engine development. A modification based upon a particular theory often fails to produce consistent results in practice, because a given clue does not lead to the cause of trouble and its cure.

Cooling and/or warming of the charge is the one sure guide to that balancing of many otherwise mysterious flow-factors entering into combustion-chamber design. Conclusions deduced from combustion-chamber shape will mislead whenever they do not conform with the heat control, which is the one decisive factor in that regulated burning which smooths power output and increases engine efficiency.

A new line of reasoning is likely to be misconstrued and misapplied because unlearning old conventions is exceedingly difficult. An illustration of scientific de-
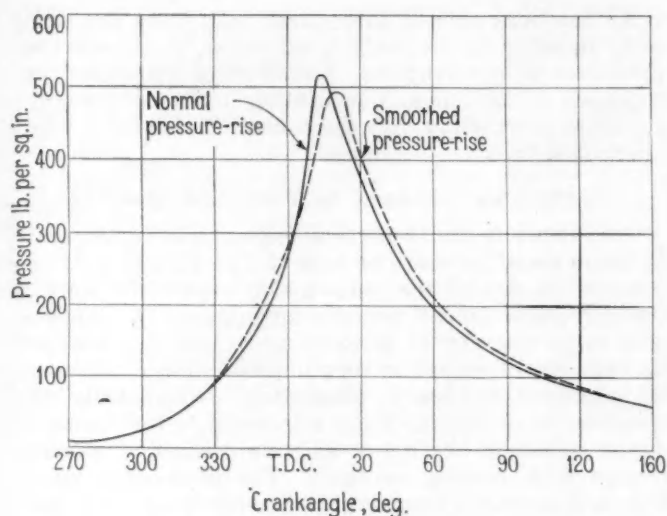
FIG. 2—DIAGRAMS OF NORMAL AND SMOOTHED COMBUSTION
IN THE WORKING STROKE OF AN INTERNAL-COMBUSTION
ENGINE

duction will demonstrate this point. Fig. 1 shows, at
the left, a swept exhaust valve which I emphasized as
the clue to the secret of detonation[7], as such a valve is
inevitably pocketed in a lateral valve-cavity forming a
heat trap. The heat trap itself was the hitherto hidden
cause of detonative combustion, but the cure for engine
knock is the abolition of the heat trap either by chang-
ing exhaust flow or by cooling the heat trap, or better
still, by both methods.

The view at the right is a photograph of an exhaust
valve that in the absence of turning during valve actu-
ation was marked by flame-flow exactly in accordance
with the idealization shown at the left. This is a swept
valve from a 1929 antiknock design of combustion-
chamber head (see Fig. 17). The knock tendency of
the valve pocket has been overcome by minimizing con-
tact of the valve head with flame and by better cooling
of the valve cavity. The combination eliminates the
heat-trap effect.

Reasoning based upon previous experience may be a
source of incorrect interpretation by a process of jump-
ing to ready-made conclusions. Thus, I pointed out
that the Hudson combustion-chamber head is trans-
formed into a non-detonative type by placement of the
spark-plug[8]. This statement has given rise to various
misconceptions regarding spark-plug location in rela-
tion to improvement in engine characteristics. Smooth-
ing of propellent inflammation is an advantage gained
as a consequence of warming the combustible followed
by firing toward a cooling zone.

Fig. 2 depicts diagrammatically the influence of
spark-plug location upon pressure rise. The continu-
ous curve marked normal pressure-rise corresponds to
central spark-plug location. The broken-line curve of
smoothed pressure-rise denotes directional firing[9] by
lateral positioning of plug, and this shows three differ-
ences:

(1) Reduction of initial lag in pressure rise owing
to an increase in flame speed due to charge being
heated by the hot exhaust-valve head

(2) Lowering of peak pressure because the flame is
continuously progressing toward the cooler zones
(3) Spreading of higher pressures over a wider
working-range consequent upon delayed burning.

Reduction in likelihood of engine knock by burning
the hottest mixture first is merely incidental, as Fig. 2
makes clearly evident. Flame speed, or rate of burning,
varies with the degree of admixture of fuel-air mix-
ture as well as its temperature. A wet, or saturated
vapor and spray, mixture burns in gasoline engines
with a sooty white flame, designated as dirty combus-
tion[10], unless the mixture becomes gaseous or dry during
the compression stroke, when clean burning results.
Furthermore, impoverishment or enrichment of the
combustible by gaseous hydrocarbons slows burning
and flame travel. Paradoxically, slow burning, in ex-
haust, arises from uneven running, with over-cool mix-
tures, and over-rich mixtures, due to overheating.

Observations on Overcooling and Flame Quenching

Regulated burning thus requires mixture-quality
control as well as limitation of heat added to the charge.
Indeed, the marvel of the internal-combustion engine is
that engine rhythm and tune are possible with a varia-
ble-speed engine carbureted with sprayed droplets of
fuel. However, the inclusion of heat in air in propor-
tion to that disappearing as latent heat of evaporation
solves the distribution part of the problem.

Another comparatively unrecognized proviso, how-
ever, is that liquid fuel should not deposit during com-
pression. Crankcase-oil dilution indicates whether this
is a regular occurrence or not, but a glance at the com-
bustion-chamber will tell its own tale in many ways
and stop unchecked theorizing.

The horsepower and fuel-consumption curves in Fig.
3 are from two streamlined cylinder-heads having the
same compression-ratio but made of cast iron and
aluminum respectively. The tester reported adversely
on the aluminum heads on the ground of less power and
greater fuel-consumption as compared with the more
knock-sensitive cast-iron head, which has a remarkably
constant spark-advance from 800 to 1800 r.p.m., making
it apparently ideal for fixed ignition.

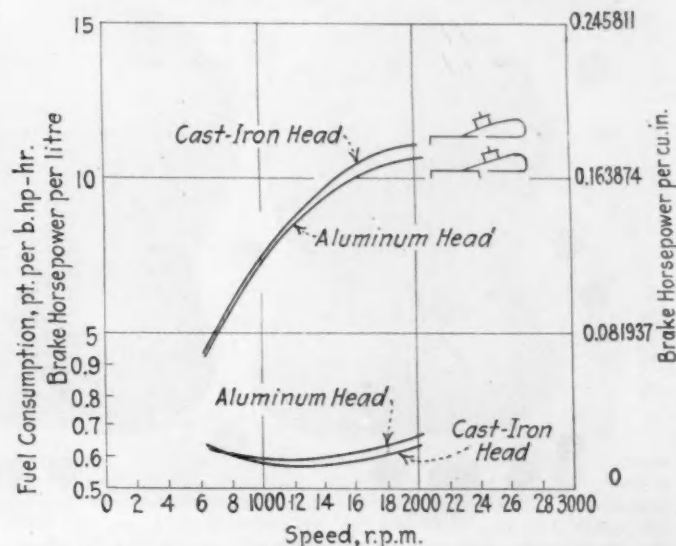Examination of the inside of the combustion-cham-

FIG. 3—COMPARATIVE HORSEPOWER AND FUEL-CONSUMPTION
CURVES FOR CAST-IRON AND ALUMINUM CYLINDER-HEADS

[7] See The Automobile Engineer, August, 1927, p. 307.
[8] See The Automobile Engineer, August, 1927, p. 311.
[9] See The Automobile Engineer, January, 1929, p. 12.
[10] See The Automobile Engineer, February, 1927, p. 56.

ber head, Fig. 4, showed that the heavy fuel used caused the failure, owing to flame quenching and fuel deposition inside the cylinder-head. Despite an outlet-water temperature of 85 deg. cent. (185 deg. fahr.), the gasoline was so difficult to volatilize and burn that only the hottest corners were well carbonized by dirty combustion. Furthermore, the flame, on striking the deflection into the cylinder, was quenched completely, as is evident by the cleanness of this partial baffle in the photograph. The clearance space is unsullied except for carbon granules representing charred droplets of unvaporized gasoline. The fuel used is abnormally heavy for British gasoline; in fact, it has a higher distillation range than Navy Specification gasoline.

The lesson to be learned is the danger of overcooling flame-swept surfaces if fuel waste is to be avoided. All that happened was that the aluminum head was clean and allowed heat to pass more quickly to the circulating water. The cast-iron head possessed fixed ignition by extra heat-retention at high speeds increasing flame speed in proportion to the engine speed. Actually, the cast-iron head cannot be used for town service, as it knocks at all speeds under load whenever water-cooling is insufficient; that is, the fixed critical ignition has changed over to a fixed knock advance.

The quenching of flame in the cooled shallow clearance space contradicts its supposed antiknock action. The engine could easily be made to knock despite the fact of the charge when compressed into clearance space being unable to burn under circumstances when it is supposed to self-ignite. Contact of combustible with an overcool surface causes sluggish uneven burning and fuel waste. The hot exhaust-valve of poppet-valve engines seems to be an advantage that sleeve-valve engines miss greatly, as shown by their excessive fuel-consumption when warming up or running light. The poppet-valve engines thus derive an advantage from a supposedly disadvantageous internal hot-spot.
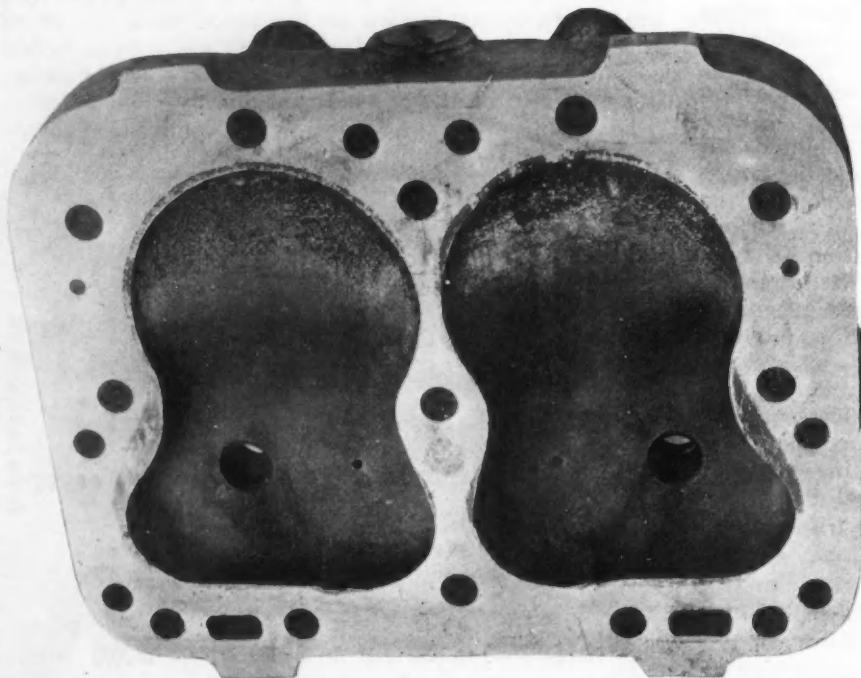
As has been shown, theoretical deductions are likely to be inverted by an analysis according to the working principles of construction. Knocking is the direct consequence of turbulent overheating and fuel waste a sequel to overcooling, but the causation thereof is often overlooked in both instances.

Turbulence Changes to Turbulent Heating

Turbulence is the theoretical explanation for increase in flame speed by more or less violent agitation of the combustible during the compression stroke. In practice the turbulent L-head permits an increase in compression ratio whereby it develops more power. However, its vagaries in regard to roughness of running discount its supposed antiknock properties. Undoubtedly the speeding up of inflammation attributed to turbulence is due to turbulent heating or eddying contact of unburnt charge with heating surfaces. The inset drawing of Fig. 5 illustrates a combustion-chamber head with overhead inlet-valve and side exhaust-valve which served to elucidate this turbulent-heating effect or flame-speed boosting.

The spark advance producing maximum power or incipient detonation can be defined as the critical spark-advance and is a measure of the fastest permissible flame-speed. Fig. 5 gives the power and critical spark-advance curves for this combustion-chamber head before and after widening the somewhat long transfer passage, as shown in the lower portion of the drawing. An increase in cross-sectional area of about 22 per cent increased the critical spark-advance over three times that calculated from the corresponding reduction in compression of 0.9 ratio. The change in critical spark-advance or flame speed after allowing for that attributable to higher compression-ratio is approximately double the differences between the flame speeds of gasolines of high and low antiknock rating, when tested with this single-cylinder experimental engine at 6.2-to-1 compression-ratio. The reduction in flame travel by minimizing turbulent heating represents a gain of two whole ratios in useful compression-ratio.

The streamlined or anti-turbulent combustion-chamber head was developed initially to prevent turbulent heating of the exhaust valve. Likewise, firing the hottest mixture first was designed to be an additional precaution against engine knock. In practice, the combination makes the combustible burn more smoothly (see Fig. 2) and more completely, while better filling increases power output as well as engine efficiency. The cooling of flame by doing work reduces flame temperature during exhaust.

An efficient non-detonating high-compression engine, despite its greater heat generation, runs cooler than a low-compression low-efficiency engine. The exhaust pipe of the experimental engine (Fig. 5) remains black-hot at a temperature of about 450 deg. cent. (842 deg. fahr.) when developing the equivalent of 35 hp. per litre (0.57 hp. per cu. in.) at 4000 r.p.m.

FIG. 4—PHOTOGRAPH OF AN ALUMINUM COMBUSTION-CHAMBER HEAD SHOWING FLAME QUENCHING AND FUEL WASTE DUE TO OVERCOOLING
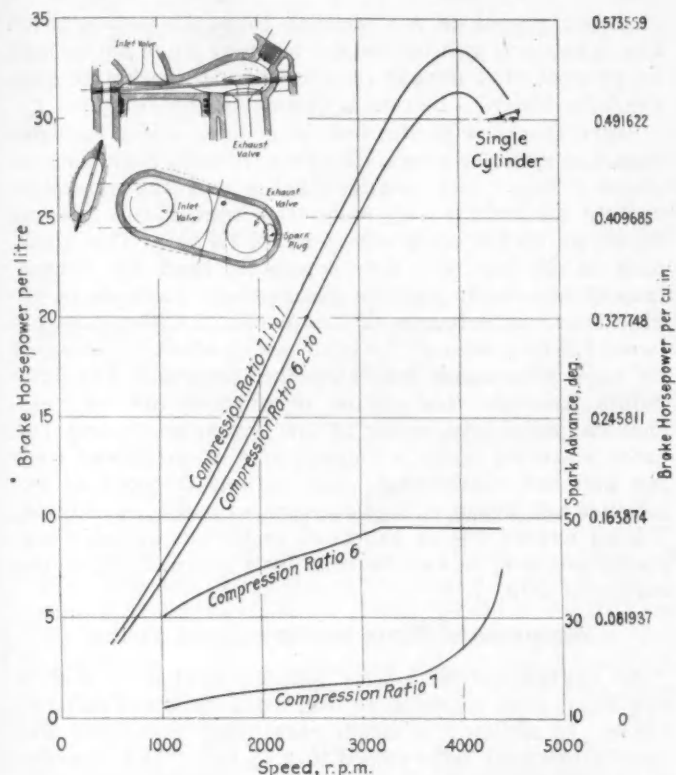
FIG. 5—POWER AND CRITICAL SPARK-ADVANCE CURVES OF A
SUPER-COMPRESSION COMBUSTION-CHAMBER HEAD SHOWING
THE EFFECT OF TURBULENT HEATING

The Curves with a 7.1 to 1 Compression Ratio Were Obtained
Before the Somewhat Long Transfer-Passage Was Widened as
Shown by the Dotted Lines in the Lower Portion of the Inset
Drawing, and the Curves with the 6.2 to 1 Compression Ratio
Were Obtained After This Change Was Made. . The Curves Were
Obtained from a Single-Cylinder Engine Developing 35 Hp. per
Liter (0.57 Hp. per Cu. In.) with a 7.1 to 1 Compression Ratio and
Having the Following Specifications: Bore, 85 Mm. (3.35 In.);
Stroke, 115 Mm. (4.53 In.); and Piston Displacement, 0.652
Liters (39.8 Cu. In.). The Maximum Brake Horsepower, 22, Was
Developed at 4000 R.P.M., the Maximum Brake Mean Effective
Pressure Was 119 Lb. per Sq. In. at 3250 R.P.M. and the Brake
Mean Effective Pressure at the Maximum Brake Horsepower Was
108 Lb. per Sq. In.

In this super-compression engine, which had a com-
pression ratio of 7.1 to 1, the polish was not burned off
the exhaust valve owing to the charge being burned
more completely *within* the engine. Reduction in tem-
perature of residual gases, and of the volume thereof,
also helps to keep the charge cooler. Hence lessened
heat waste not only averts the evil effects of destructive
heating of valve-heads and valve-seats but also inverts
the supposedly inherent knock tendency of high com-
pression-ratio.

Modern Engine Practice

The decision by an engine manufacturer to use a
specific type of engine is dictated by some special con-
sideration such as (*a*) mass production of automobiles,
(*b*) silent, smooth and flexible luxury cars, (*c*) accel-
eration in sport models and (*d*) efficiency and service
in commercial vehicles. Nowadays the choice normally
narrows down to side-by-side valve engines for low-
priced automobiles and heavy-duty motor-trucks and
overhead-valve engines for fast cars and low-loading
motorcoaches.

An all-round endeavor is being made to secure
smoother running by antiknock combustion-chamber
heads. Another decided trend is to increase the num-
ber of cylinders and revolution rate for maximum power
so as to obtain greater flexibility. Maintenance of tune
and quietness in service has kept the cheaper engine in
favor, despite its lower power-output.

In Great Britain during the last two years a distinct
trend has been noticed toward return to small-bore L-
head engines at the expense of valve-in-line push-rod-
operated engines, owing to the former requiring less
attention. On the other hand, the introduction of high-
speed long-distance motorcoaches is leading to a more
extended use of overhead-valve engines in commercial
chassis, because the removal of the valves along with
a detachable head allows a quick change-over of com-
bustion-chamber heads without taking the vehicle out
of service. Modern engines are expected to give good
efficiency and power output at all engine speeds up to
3000 r.p.m. The task is not difficult as regards either
L-head or I-head engines except when the demand for
smoothness and flexibility becomes insistent or even
imperative, when failure or success becomes entirely a
matter of control of the combustion rate.

Limitations Due to Type of Head

One object of this paper is to indicate some of the
limitations imposed upon induction as well as combus-
tion following the selection of a particular form of
combustion-chamber and to describe how these can
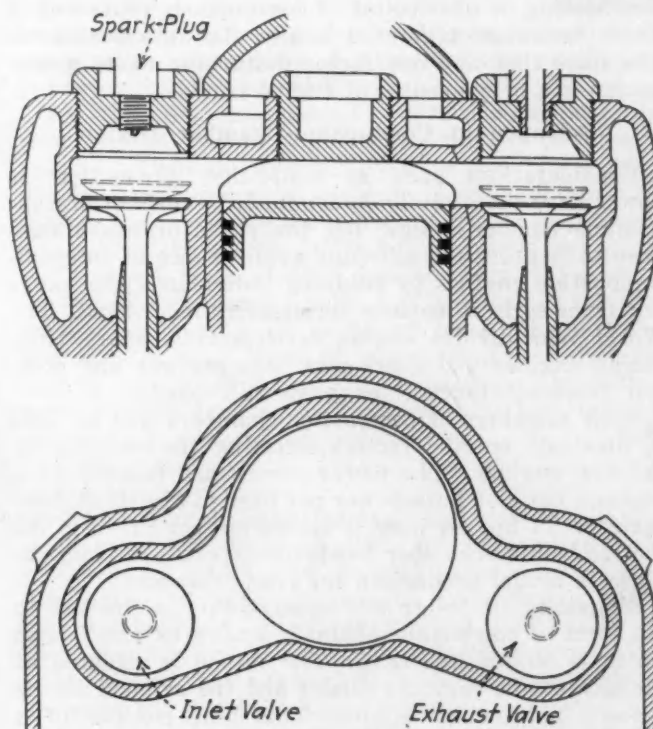sometimes be partly or wholly overcome. The examples

FIG. 6—T-HEAD COMBUSTION-CHAMBER
This Head Was Applied to a Low-Speed Four-Cylinder Engine
Developing 8.5 Hp. per Liter (0.1394 Hp. per Cu. In.) with a
4 to 1 Compression Ratio and an Improved Engine Developing
12.5 Hp. per Liter (0.2048 Hp. per Cu. In.) with a Compression
Ratio of 4.75 to 1. The Cylinder Specifications Were Bore, 127
Mm. (5.0 In.); Stroke, 180 Mm. (7.1 In.) and Piston Displace-
ment 9.12 Liters (556 Cu. In.)

Form	Constructional Reason	Controlling Characteristics
Pre-War Types		
T-Head	Simplicity	Separation of intake and exhaust
L-Head	Cheapness in production	Juxtaposition of intake and exhaust
Post-War Types		
Ricardo	Thermal efficiency	Reduction of cooling area and internal resistance
Overhead Valve	Power	Increased pumping capacity
Whatmough	Efficiency, power and smooth burning	Streamlined flows of intake and flame

are selected for various reasons but usually to show how power output and antiknock characteristics can be affected greatly by simple changes in the flow form of the combustion-chamber.

Powerful, efficient and smooth engines meeting all trade requirements can be equipped with side-by-side valves, but a flat or extended combustion-chamber head necessitates more careful correction of heat-flow or temperature distribution than engines having a rounded or more compact combustion-chamber. Cooling and heating effects vary greatly during the working cycle and also in different parts of the cylinder to an extent that automobile engineers seldom realize.

The question of good and bad combustion-chamber design is mainly a matter of whether any trend toward overheating or overcooling is continuously redressed or these become exaggerated locally. In anticipation we can state that any one factor disturbing flame propagation is a prime source of engine trouble.

Advance in Combustion-Chamber Design

Considerations such as simplicity, production or power have successively determined the fashion in combustion-chamber design, but the endeavor has always been to improve the all-round performance of internal-combustion engines by studying individual types ranging from early to modern forms of cylinder-head. The World War divides engine developments, apart from racing engines and sport cars, into pre-war and post-war types substantially as given in Table 1.

Scale drawings of combustion-chambers will be used to illustrate specific factors affecting the working of gasoline engines. The power curves are reduced to a common basis of horsepower per liter to aid strict comparison. [1 hp. per liter = 0.0164 hp. per cu. in.]. All the combustion-chamber heads except one are from engines in actual production for road transport.

Simplicity in design and construction is the key to the form of combustion-chamber known as the T-head which is shown in Fig. 6. The intake is situated at one side of the central cylinder and the exhaust at the opposite side of the engine. This head consists of a chamber of even depth with the clearance space subdivided into three components, (*a*) lateral intake pocket, (*b*) central clearance and (*c*) exhaust-valve cavity.

In this engine, during the periodic displacements of the piston, the inlet valve and pocket are cooled by evaporation of ingoing fuel and the exhaust-valve head is heated by flame. Whenever the central combustion-

chamber proper is cool enough to avoid auto-ignition the intake acts as a condenser, whereas when hot enough to prevent fuel deposition the exhaust pocket is particularly likely to become a detonative heat-trap.

Interference with the flow of cooling water by valve caps and cylinder plugs, cast-iron pistons, high-temperature exhaust and residual gases and thermosyphon cooling all combine to make the engine run hot, as shown by its low compression-ratio, 4.0 to 1. The spark-plug on the inlet side fires across the head into a heat-trap of the worst possible description. Increase in engine speed accentuates the temperature differences between the two sides of the head, which effect is increased by caps preventing water-cooling thereof. The only points favoring this engine in practice are (*a*) mechanical reliability owing to low engine-speed and (*b*) quick warming-up as a consequence of inefficient cooling and bad scavenging. Limitations in work of expansion and waste of fuel combine to make the original T-head engine one of the most inefficient among four-stroke engines, as can be seen by a comparison of the curves of Fig. 7.

Improvement Made by Directional Firing

An engine having a head similar to that in Fig. 6 was fitted with spark-plugs over both inlet and exhaust valves. In addition, a larger carbureter was fitted and the compression ratio raised to 4.75 to 1. The increase in horsepower was considerable, as can be seen from Fig. 7. Dual ignition with firing over the exhaust valve thus permits the use of a high compression-ratio and a fuller use of the pumping capacity of the engine. The raising of the useful compression-ratio is testimony from a combustion-chamber head possessing inherent knock characteristics of the antiknock virtue of directional firing; that is, clearing combustible from the exhaust-valve pocket before a detonative pressure-rise is attained.

The saving of a camshaft, as compared with the T-head engine, was the original reason for the introduction of the L-head or side-by-side-valve engine. Its popularity as a production engine arises from both relative cheapness in manufacture and quietness in running after much service. The juxtaposition of the inlet and exhaust valves in the same lateral valve-capacity constitutes an advance in combustion-chamber design, which up to the present has hardly been appreciated. The cooling of the inlet valve and the heating of the exhaust valve counteract each other to a certain extent, which materially lessens fuel waste and increases permissible engine efficiency.

More experimenting has been done upon engines with side-by-side valves than upon all other types of cylinder-heads combined, and the antiknock theory of combustion-chamber design revolves around results obtained from various forms of L-head engine. The original L-head consisted of a combustion-chamber of even depth extending over the cylinder barrel and over a lateral valve-cavity. The valve cavity is on one side of the cylinder only, so the chamber is a little deeper and has less surface than the T-head of corresponding compression-ratio.

Engines of modern design may still embody the essential features of the original L-head, which in its simplest form is represented by the dash lines in Figs. 8 and 9. The development consists of several stages, one
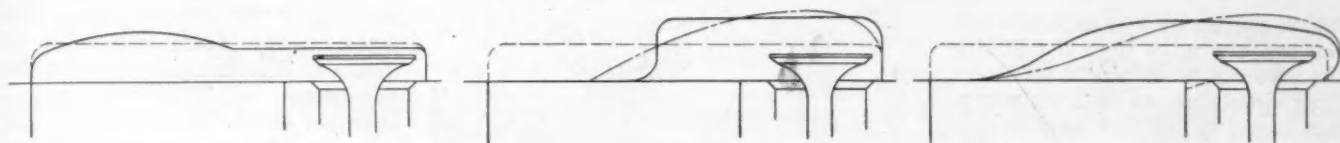
FIG. 8—DIAGRAMMATIC COMPARISONS OF L-HEAD FORMS

The Original Head in Its Simplest Form Is Indicated by Dash Lines in All Three Views. The Forms with Which the Comparison Is Made Are Indicated by the Full and Dot and Dash Lines and Are (Left) Restricted Head, (Center) Turbulent (Full Line) and Semi-Turbulent (Dot and Dash Line) Heads and (Right) Two Anti-Turbulent or Streamlined Heads

of which is definitely retrograde. For classification purposes these heads can be designated as

(1) Retrograde or restricted L-heads
(2) Improved L-heads
    (a) Sloping-roof L-heads
    (b) L-heads with inclined valve-cavity
    (c) Turbulent heads
    (d) Semi-turbulent L-heads
    (e) Streamlined or anti-turbulent L-heads

The evolution of the different forms of L-head is easily followed from the three views of Fig. 8, which from left to right show restricted L-head, turbulent and semi-turbulent L-heads and anti-turbulent L-head. For convenience in explanation and description, L-head engines can be divided first, into low-speed large-bore engines for commercial vehicles and high-speed small-bore engines for automobiles, and then further subdivided into special types, such as turbulent, anti-turbulent and the like.

Low-Speed Engines

Engines for commercial use have up to the present been characterized by developing maximum torque at a
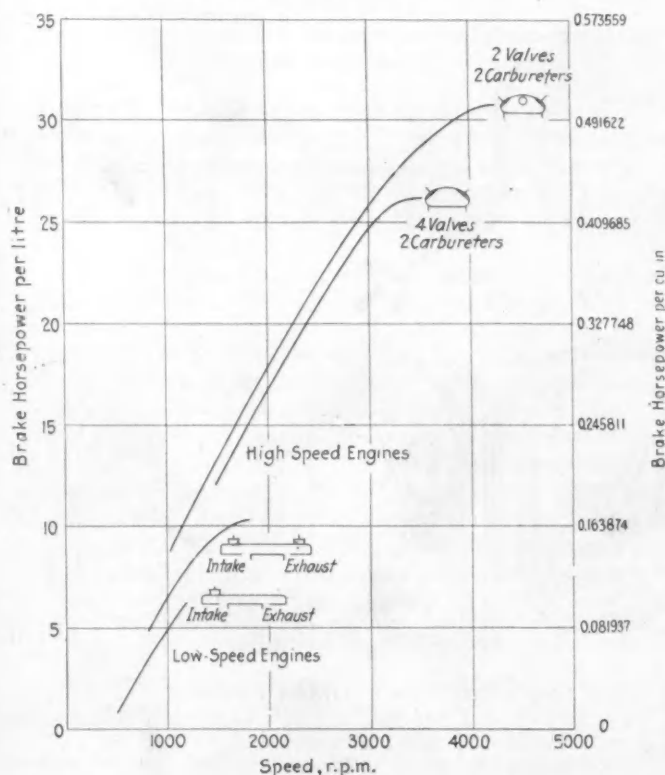
FIG. 7—COMPARISON OF ANCIENT LOW-SPEED AND MODERN HIGH-SPEED ENGINES EXPRESSED IN HORSEPOWER DEVELOPED PER LITER (1 HP. PER LITER = 0.01639 HP. PER CU. IN.)

relatively low speed, below 1000 r.p.m. Maximum power is ordinarily attained at from 1600 to 2000 r.p.m. Usually a falling off of some 40 per cent in brake mean effective pressure occurs between maximum torque and maximum power, due to restriction that may be external, at the carbureter throat or at the inlet valve, or internal, at the transfer passage leading from the valve cavity to the cylinder barrel.

Fuel economy is attained by making the engine run hot, and this limits the compression ratio to between 4 to 1 and 5 to 1. The lower ratio is approached with cast-iron pistons and the hgher ratio when aluminum pistons and an improved type of combustion-chamber are employed. The reduction in the quantity of charge burned per working stroke at higher speeds counteracts considerably the conversion of the exhaust-valve cavity into a heat trap by overheating during exhaust. Any attempt to increase the working efficiency of large-bore engines is likely to meet with failure owing to the roughness and engine knock arising from auto-ignition whenever increased power-output is obtained from a given cylinder-capacity. Thus, in low-speed engines the effective compression-ratio may be reduced to nearly one-half at higher speeds. Any increase in working pressure necessitates also taking extra precautions to prevent excessive local heating.

The following examples of combustion-chambers are from engines used in public-service vehicles or for commercial transport. The left view of Fig. 10 shows a simple improvement of ordinary L-head obtained by sloping the roof from the valve cavity toward the opposite side of the cylinder. The engine reproduces all the bad features of the T-head design shown in Fig. 6. It is used in motorcoach service and is notorious for hammering under load. A turbulent head, which is now standard in later types of engine employed upon the same service, is illustrated in the central view. This is more efficient but is still rougher in action, owing to turbulent heating of the exhaust valve. The flame is also projected violently against the top of the piston at one side only, which is a cause of the breaking of the struts of the split-skirt pistons. The view at the right depicts a combustion-chamber of streamline form, which along with better water cooling, owing to the elimination of valve caps, permits a considerably higher compression-ratio. However, central ignition in the main combustion-chamber allows flame to proceed into a hot pocket. The engine still knocks at low speeds and is somewhat rough at high speeds.

Fig. 11 gives the power curves from the three combustion-chamber heads of Fig. 10. These were tested under identical conditions on the same cylinder-block, detachable heads being used to make strict comparison possible. Interest lies in the increase in power due to raising of the compression ratio and better flow-lines. A noteworthy gain in power and an extension of revo-

lution rate, which is evident from the top curve, is typical of using the outer side of the inlet valve. This simply means that the pumping capacity of the engine has been increased owing to the effective valve area being enlarged. In all three instances the engine is rough-running on full load, owing to firing into an excessively hot exhaust-valve pocket.

The detachable L-head was introduced to permit valve-grinding without removing the cylinder-block. The view at the left of Fig. 12 depicts a 20-year-old type of engine that still gives excellent service. The engine is decidedly robust in design, which is an improved L-head with sloping roof. The running is not rough but the engine lacks power compared with modern standards. The inlet-valve caps are retained but their removal would lessen the heat-trap effect over the exhaust valve. The central drawing is of a turbulent head that has replaced the original design for some years past. Though it has given the

necessary power increase, the engine now develops a distinct period at 1600 to 1800 r.p.m., which can be felt throughout the chassis. The two causes for this vibration are (a) side thrust of flame and (b) turbulent
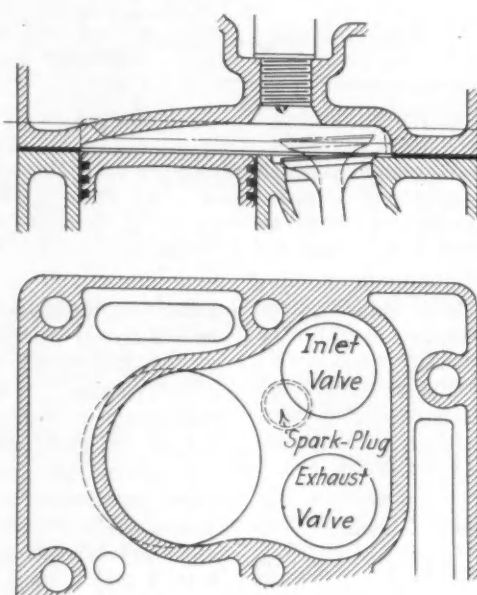
FIG. 9—AN APPLICATION OF THE L-HEAD TO A HIGH-SPEED SIX-CYLINDER ENGINE

The Cylinder to Which the Head Was Applied Had the Specifications Given Below

Bore	63.5 mm.	2.50 in.
Stroke	101.0 mm.	3.98 in.
Piston Displacement	1.919 liters	117.00 cu. in.

heating of the exhaust valve. The latter arises from deflection of flame, during exhaust, against the flat dome of the combustion-chamber to the outer edge of the exhaust-valve head. The roughness is definitely due to auto-ignition, as shown by the engine continuing to fire, with the ignition cut-off, after running on heavy load until maximum roughness is obtained. The drawing at the right shows an anti-turbulent head designed to eliminate high-speed roughness in running. Not only was this objective attained but a marked increase in power output was secured by removal of restriction at the inlet valve. The anti-turbulent head showed a decided tendency to knock at 800 r.p.m. when the throttle was suddenly opened on heavy load, due to the formation of steam pockets.

Fig. 13 includes power curves from all three detachable heads. A flat and extended power-peak from 2000 to 3000 r.p.m. is particularly desirable for long-distance high-speed motorcoach service. In this class of vehicle the engine is working at more than 2000 r.p.m. for long periods and the power should not fall off with increase in engine speed. The number of revolutions per minute attained during road
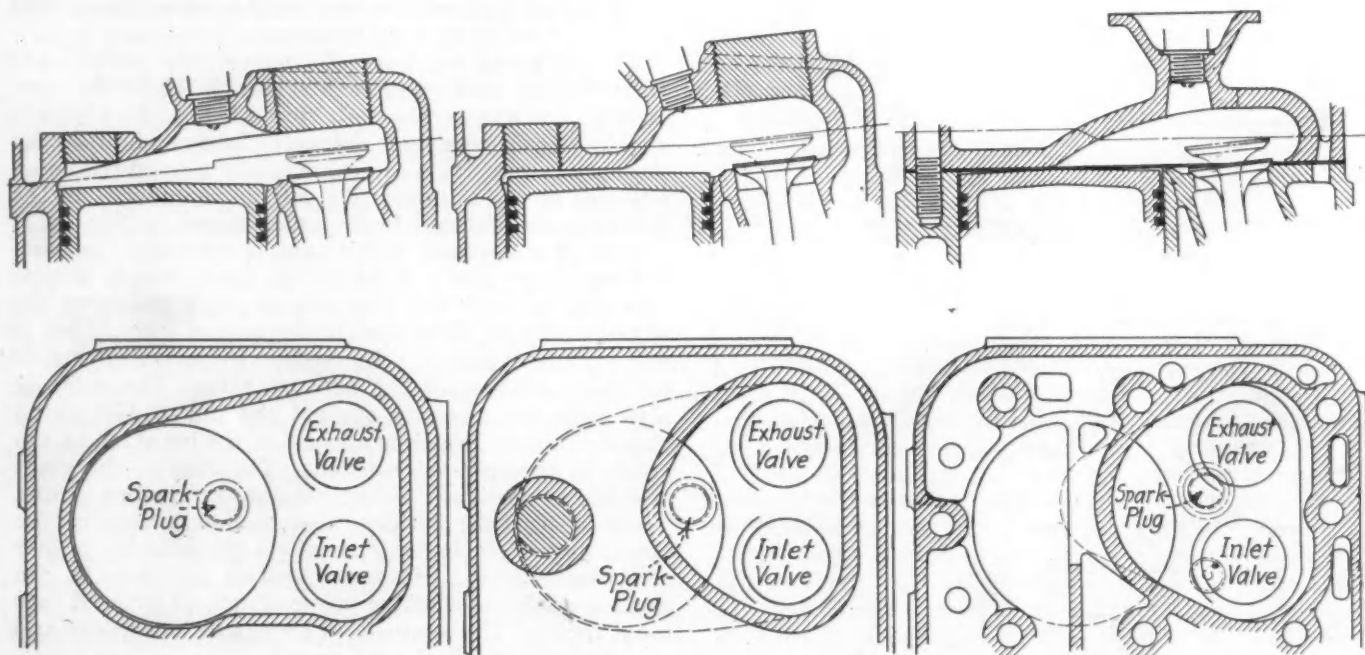

FIG. 10—THREE EXAMPLES OF L-HEADS USED WITH LOW-SPEED FOUR-CYLINDER ENGINES

The Cylinder Dimensions of All Three Engines Were Bore, 108 Mm. (4.25 In.); Stroke, 140 Mm. (5.5 In.) and Piston Displacement 5.13 Liters (312 Cu. In.). Other Details of the Engines Are Tabulated Below

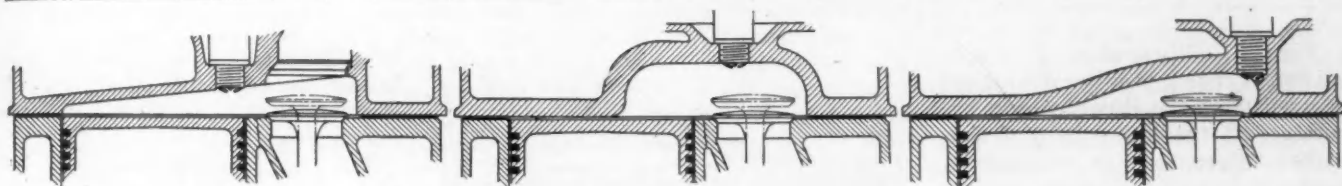| Type of Head	Inclined Roof	Turbulent	Anti-Turbulent
Power, hp. per liter	8.30	10.00	11.1
Power, hp. per cu. in.	0.1360	0.1639	0.1861
Compression Ratio	4.2 to 1	4.8 to 1	5.0 to 1
Maximum Power, b.hp.	42.5	51.0	62
Speed at Which Maximum Power Was Developed, r.p.m.	1,500	1,600	2,300

FIG. 12—THREE MORE APPLICATIONS OF L-HEADS TO LOW-SPEED FOUR-CYLINDER ENGINES

All Three Engines Had the Same Cylinder Dimensions; Bore, 114 Mm. (4.5 In.); Stroke, 146 MM. (5.75 In.), and Piston Displacement, 5.99 Liters (366 Cu. In.). Other Details Are Tabulated Below

Type of Head	Inclined Ceiling	Turbulent	Anti-Turbulent
Power, hp. per liter	10.2	11.3	13.3
Power, hp. per cu. in.	0.1710	0.1852	0.2180
Compression Ratio	4 to 1	5 to 1	6 to 1
Maximum Power, b.hp.	61	68	80.
Speed at Which Maximum Power Was Developed, r.p.m.	2,200	2,200	2,400
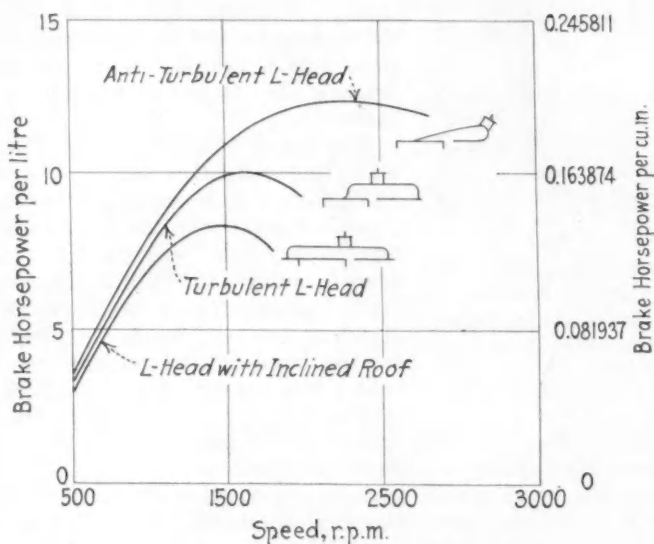
FIG. 11—HORSEPOWER CURVES FROM IMPROVED, TURBULENT AND ANTI-TURBULENT L-HEADS

running is much higher than would be expected from bench tests. With the engine in question a 32-passenger coach, starting from rest, accelerates to 30 m.p.h. within 20 sec. The road speeds during this performance represent engine speeds well over 3000 r.p.m. on the lowest two gears.

Fig. 14 shows at the left an L-head in which the passage between the valve cavity and the cylinder barrel is unrestricted owing to the inclination of the valves. In this case the inlet valve limits the pumping capacity of the combustion-chamber head. This head is particularly prone to knock, owing to firing into a heat trap over the exhaust valve. The view at the center shows the engine redesigned on anti-turbulent lines. The comparative power-curves in the chart at the right again demonstrate that using the outer side of the inlet valve increases engine torque throughout the working range. In this instance the brake mean effective pressures are included to illustrate this point.

High-Speed Engines

Maximum engine-speed increases according to the extent to which any restriction upon the pumping capacity is removed either in the induction system or the cylinder-head. However, the latter is usually not done to the best advantage and may even be retrograde, as in the restricted L-head type shown in Fig. 16.

Fig. 9 depicts an L-head from an engine of recent design which is definitely restricted in power output

owing to the flatness of the valve cavity. The proposed conversion, shown in Fig. 15, should give much smoother running and 20 per cent more horsepower per liter.

In Fig. 16 the main combustion-chamber over the cylinder is seen to be enlarged at the expense of the lateral valve-cavity, which retrograde step brings back the defects of the T-head; namely, restriction and overheating. This combustion-chamber design represents a small-bore, high-speed motor-car engine that would pre-ignite badly were it not that the nominal compression-ratio of 4.8 to 1 is considerably cut down by bad filling, as shown by the maximum brake mean effective pressure being only 84 lb. per sq. in. On the road the engine generates roughness at moderate engine-speeds and is an inveterate "pinker" at the higher speeds. Despite thermosiphon cooling, it is very slow to warm up, owing to the large cooling surface of the main combustion-chamber.
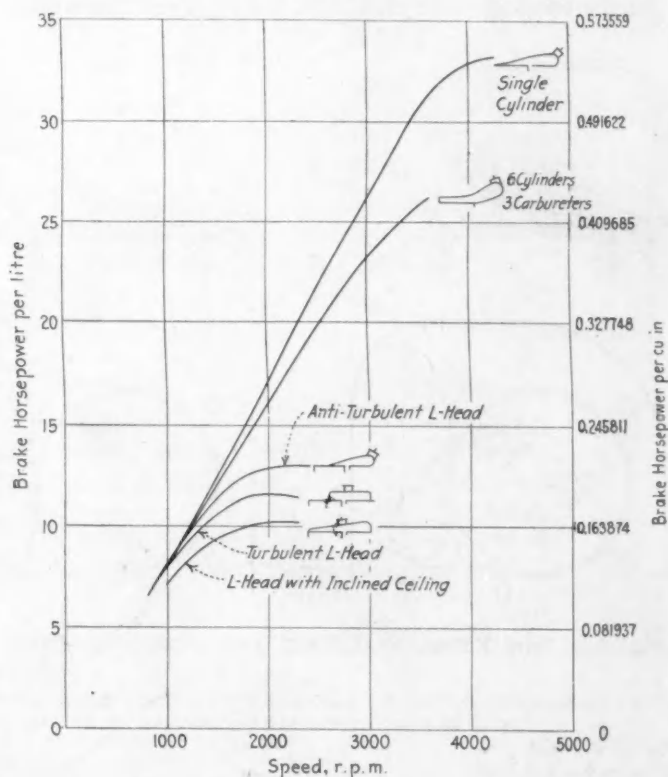
FIG. 13—POWER CURVES FROM LOW AND HIGH-SPEED L-HEAD ENGINES SHOWING INCREASING PEAK POWER PER LITER FOLLOWING REMOVAL OF RESTRICTION UPON PUMPING CAPACITY OF ENGINE

Fig. 17 illustrates a semi-turbulent head that is obviously derived from the Ricardo head by cutting off the lower half of the baffle interposed in turbulent heads between the valve cavity and the cylinder. The top of the cylinder-block is set at an angle which gives a wedge-shaped clearance space between the top of the piston and the cylinder-head. This lessens the side thrust of flame upon the piston. The partial stream-lining of the transfer passage between the valve cavity and the cylinder also helps in this respect. The effective area of this passage is exceedingly important because bringing the slope toward the cylinder too close to the valve cavity has two effects: (a) an increase in the internal resistance of the engine or diminution of its pumping capacity and (b) an increase in the side thrust of flame upon the piston.

Fig. 18 is interesting as it represents one of my first attempts to produce an antiknock head, in the course of which a difficulty arose in making the transfer passage large enough. On the principle that to have the best-flow lines around the exhaust valve was necessary, the lateral cavity was domed on the exhaust-valve side only, the required diminution

FIG. 15—ANTI-TURBULENT HEAD APPLIED TO A HIGH-SPEED SIX-CYLINDER ENGINE

The Engine Had a 6 to 1 Compression Ratio and the Following Cylinder Dimensions: Bore, 63.5 Mm. (2.5 In.); Stroke, 101 Mm. (3.98 In.) and Piston Displacement, 1.919 Liters (117 Cu. In.)

in clearance volume being obtained by flattening the roof of the combustion-chamber over the inlet valve.

The two combustion-heads of Fig. 17 and 18 yielded power curves that were almost identical, the power output being 18 hp. per liter (0.29 hp. per cu. in.) at 2400 r.p.m. Tests show that the flow is restricted at the inlet valve in the antiknock head shown in Fig. 18 so that poorer filling nullified the gain from higher compression-ratio. The standard head was fairly smooth, but the Whatmough head was a definite improvement despite its higher compression-ratio.

The car in question is a British six-cylinder light car of 2¼-liters (137.37-cu. in.) capacity and, though a relatively cheap production-model, the engine has a seven-bearing crankshaft. Automatic spark-advance is fitted as standard, but both heads "tinkled" on the road when the car was held at its maximum speed of 55 to 60 m.p.h. for 5 min. or so. The chief difference noted was that the head in Fig. 18 required retarding as speed increased, whereas with the original head the advance was correct at all speeds.

Fig. 19 represents the final combustion-chamber de-
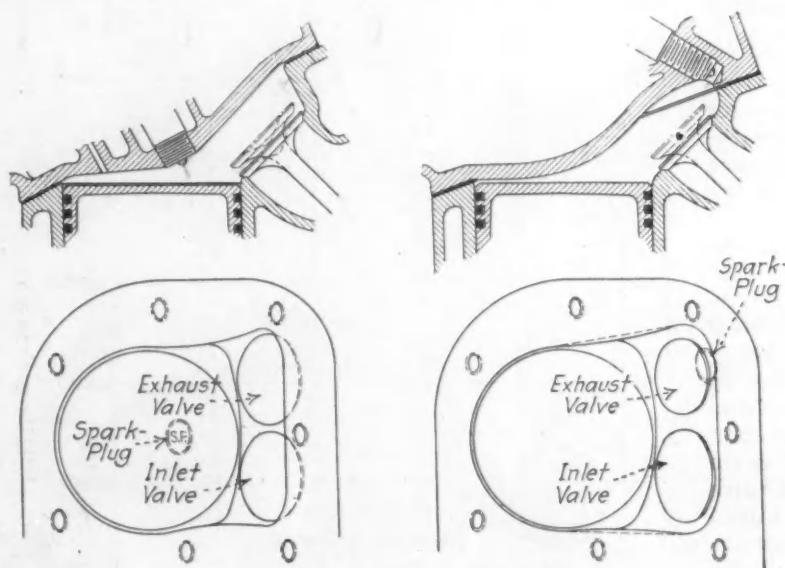
FIG. 14—TWO FORMS OF L-HEAD AND CURVES OF BRAKE HORSEPOWER AND BRAKE MEAN EFFECTIVE PRESSURE DEVELOPED BY EACH

The Low-Speed Four-Cylinder Engine to Which These Heads Were Applied Had a Bore of 108 Mm. (4.25 In.); a Stroke of 140 Mm. (5.5 In.) and a Piston Displacement of 5.12 Liters (312 Cu. In.). Other Data Are Tabulated Below

Type of Head	Unrestricted Transfer Passage	Streamlined Intake
Power, hp. per liter	10.3	11.3
Power, hp. per cu. in.	0.1688	0.1852
Maximum Power, b.hp.	52.5	58.5
Speed at Which Maximum Power Was Developed, r.p.m.	1,950	2,000
Maximum Brake Mean Effective Pressure, lb. per sq. in.	93	100
Speed at Which Maximum Brake Mean Effective Pressure Was Developed, r.p.m.	900	900
Brake Mean Effective Pressure at Maximum Power, lb. per sq. in.	67	72
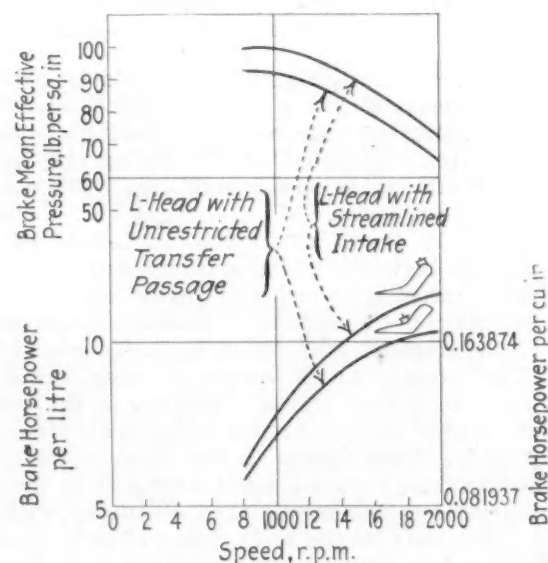
sign as fitted to my own car, and the following points are of interest regarding this head, which had a compression ratio of 6.1 to 1. The pocketing of the spark-plug in a water-cooled cavity has definitely removed all symptoms of pinking at any engine-speed or load. In particular, the high-speed "tinkle" has gone and the spark advance is the same as on the original engine,

[11] See *The Automobile Engineer*, August, 1928, p. 293.

showing that a reduction in flame speed was made.

The engine in question is fitted with an Autostat and a super-spraying carbureter, fulfilling all the conditions necessary to assure complete flexibility[11]. The combination entirely eliminates roughness and a peculiar result of enhanced smoothness is the quieting of gear hum in both engine and transmission. The acceleration is decidedly improved, although the absence of roughness is deceptive. The top-gear performance is phe-
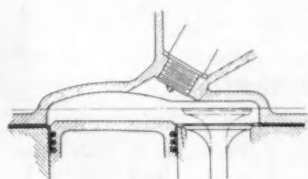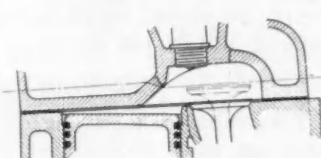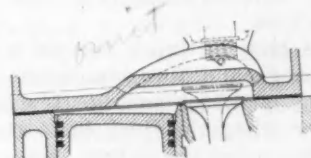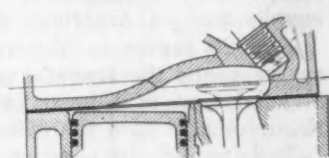
FIG. 16   FIG. 17   FIG. 18   FIG. 19
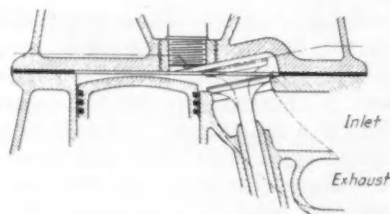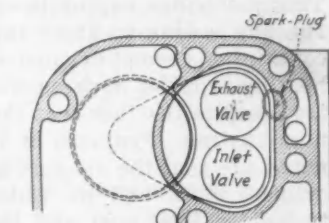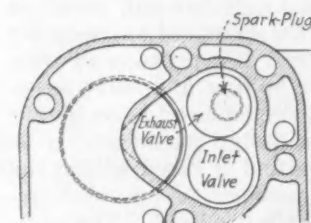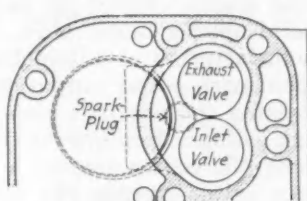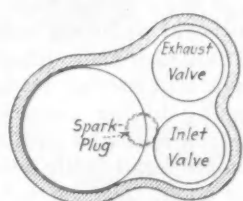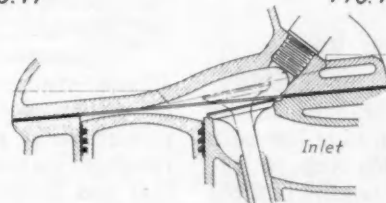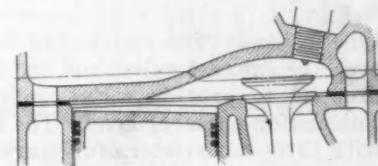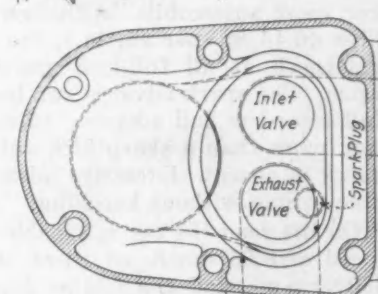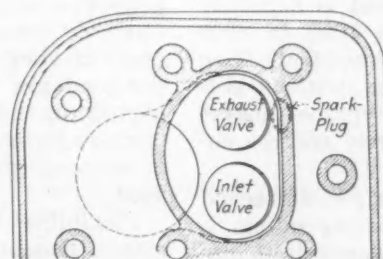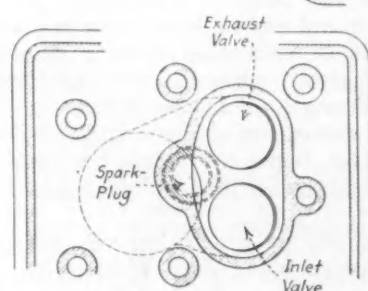
FIG. 20   FIG. 21   FIG. 22

APPLICATIONS OF L-HEADS TO HIGH-SPEED SIX-CYLINDER ENGINES

The Data on the Various Engines Are Tabulated Below

Fig. No.	16	17	18	19	20	21	22
Type of Head	Restricted	Semi-Turbulent	Anti-Turbulent with Inlet-Valve Restriction	Anti-Turbulent	Unrestricted	Anti-Turbulent	Super-Efficient
Power, hp. per liter	....	....	....	....	20	26.2	33.5
Power, hp. per cu. in.	....	....	....	....	0.3277	0.4294	0.5490
Bore, mm.	69	65.5	65.5	65.5	65	65	85
Bore, in.	2.72	2.58	2.58	2.58	2.56	2.56	3.35
Stroke, mm.	110	111	111	111	115	115	115
Stroke, in.	4.33	4.37	4.37	4.37	4.53	4.53	4.53
Piston Displacement, liters	1.645	2.244	2.244	2.244	2.29	2.29	0.652
Piston Displacement, cu. in.	100	137	137	137	140	140	39.8
Compression Ratio	4.8 to 1	5.25 to 1	6.25 to 1	6.1 to 1	5.2 to 1	....	6.1 to 1
Maximum Power, b.hp.	33	....	....	....	45	60	22
Speed at Which Maximum Power Was Developed, r.p.m.	3,200	....	....	....	3,000	3,600	4,250
Maximum Brake Mean Effective Pressure, lb. per sq. in.	84	....	....	....	96.5	104	120
Speed at Which Maximum Brake Mean Effective Pressure Was Developed, r.p.m.	....	....	....	....	1,000	1,500	3,000
Brake Mean Effective Pressure at Maximum Power, lb. per sq. in.	....	....	....	....	85.1	94	100

nomenal, as the engine will pull on full-open throttle against the brake down to 4 m.p.h. The cruising speeds of the car up to 40 m.p.h. are so smooth as to deceive experienced drivers as to the actual speed. The engine runs without vibration on full throttle at all speeds until a critical period is generated at 58 m.p.h.

Independent tests by *The Motor*[12] prove that a 6-to-1 compression ratio, anti-turbulent head (Fig. 17) will run on low-grade British gasoline without the slightest symptom of roughness or knock. The car also runs equally well on American gasoline.

Fig. 20 serves to illustrate how inclining the valve cavity opens the transfer passage and forms an unrestricted type of L-head having a direct passage from the inlet port into the cylinder when the inlet valve is fully lifted in the position shown by the dotted lines. This particular engine is exceedingly hot and rough in running, owing to firing into the extended valve-cavity containing a swept exhaust-valve. It is prone to all overheating troubles such as water boiling and valve burning, despite the fact that the cylinder-head is an aluminum casting. Features of this design which should be noted are that the exhaust manifold is cored within the cylinder-block and no water passage is provided between the inlet port and the cylinder-head. The combined effect results in bad and continuous overheating of the valve side of the engine.

Anti-Turbulent Design Free from Knock

Fig. 21 illustrates a conversion to an anti-turbulent-type L-head. The spark-plug is now arranged to fire over the exhaust valve, and the induction pipe has been dropped to provide water-cooling to this side of the combustion-chamber head. The modified engine is fitted with three carbureters for marketing as a four-passenger sport automobile. Although it develops 28 hp. per liter (0.46 hp. per cu. in.), the new head is definitely antiknock at all full-load speeds from 1000 to 4000 r.p.m. The spark advance can be shifted suddenly from full retard to full advance, 10 to 45 deg., without getting more than a sharp kick out of the engine; engine knock is absent. Excessive advance merely reduces engine torque without knocking.

On the road the car is capable of 42 m.p.h. on second speed and 65 m.p.h. on third speed, corresponding to 4600 r.p.m., and the engine is not distressed in any way. The maximum speed on high gear is more than 80 m.p.h. When warmed up, the modified engine is exceedingly flexible on high gear, being free from thump or knock at stalling speeds on hills. The acceleration in gear has all the bite necessary for this type to sell as a sport model. Incidentally, the engine could be improved by using smaller valves which would permit of a more compact combustion-chamber and a larger transfer passage between the cylinder and the valve cavity. The gain in space would also allow the compression ratio to be increased beyond 6 to 1 without impairing volumetric efficiency.

Fig. 22 illustrates the advantages of streamlining and balancing all the flows in an anti-turbulent L-head. Special water-cooling between the valve-seats widens the head and also necessitates a longer transfer passage, the consequence being that the height of the dome has to be reduced. The dimensions were determined by bench tests with a single-cylinder engine, the final com-

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[12] See *The Motor*, April 30, 1929, p. 589.

pression-ratio being 6.1 to 1. The effective resistance of the inlet-valve port and of the transfer passage is so exactly balanced that any increase or decrease in the thickness of the gasket will lower the power output.

The power curve in Fig. 13 shows that it is possible to make a side-by-side-valve engine peak at 4250 r.p.m. and give excellent filling to well over 3500 r.p.m. The power curve is virtually a straight line up from 1000 to 3500 r.p.m. The engine can be run continuously at 3000 r.p.m. without any sign of roughness, although the torque developed represents a brake mean effective pressure of 129 lb. per sq. in.

Overhead-Valve Engines

The valve-in-head engine has had a long vogue in America as a high-speed engine because it can give considerably greater efficiency than the less costly L-head engine. Motor-car taxation in the British Isles is based upon cylinder bore, and post-war taxation made manufacturers of automobiles concentrate their efforts upon more power output per taxed horsepower by increasing the engine speeds and using higher compression-ratios. Engines with push-rod-operated valves along the center line of a detachable head with overhead valves became the mode for medium-price automobiles until very recently, when the need for quiet valve-operation has led to improved L-heads regaining lost ground.

The compact combustion-chamber of overhead-valve I-head engines should be almost fool-proof according to theory, yet it disappoints in practice. Whenever plentitude of power is obtained on the test bench, the resultant automobile is a noisy sport car instead of the fast and flexible speed type. The close juxtaposition of cool inlet and hot exhaust disturbs the working heat-balance. Whenever the head is sufficiently cooled to prevent autoignition and engine knock, the engine runs unevenly because it is overcooled from a combustion point of view. Conversely, when the walls of the cylinder-head are hot enough to assure absence of flame quenching and fuel deposition at low engine-speeds, the mixture burns too fast, hence the engine becomes rough at high speeds and pinks on load unless doped fuel is used.

Flexibility is secured by sacrificing volumetric efficiency, small-bore pipes being used along with intensive exhaust heating at sharp bends. The consequence is that the pumping capacity of automobile engines with overhead in-line valves seldom approaches realizable efficiency. However, one British small-bore six-cylinder engine develops 28 hp. per liter (0.46 hp. per cu. in.) at 4500 r.p.m. Designs have been made of three distinct types of I-heads embodying Whatmough principles that smooth combustion and overcome induction limitations upon flexibility. I am not at liberty to give any details except that the first engine completed is definitely antiknock, despite excellent power output.

Hemispherical combustion-chamber heads are popular with British automobile manufacturers specializing on high-speed cars. Unfortunately, as already explained, compact heads are subject to overcooling and overheating troubles, and ultra-high speeds only accentuate these drawbacks. Bad burning, due to the rich carbureter settings for rapid acceleration, make sport automobiles run well only at high rates of revolution. The driver attains and maintains a high average road-speed by much gear-changing.

The drawing at left of Fig. 23 is a reproduction of a hemispherical combustion-chamber head with inclined valves arranged in almost straight-through ports. This head had been highly developed by motorcycle manufacturers, and a power output of over 40 hp. per liter (0.65 hp. per cu. in.) is rather common in single-cylinder engines that are unhampered by external and internal overcooling caused by fuel deposition during induction and compression. The pumping capacity of the hemispherical head makes it for the time being preeminent for racing competitions, especially as supercharging overcomes the carburetion and distribution difficulty to a great extent. A corresponding increase in engine efficiency is secured, but excessive doping of fuel is essential as a knock preventive.

The design of cylinder-head having more than one inlet valve and/or one exhaust valve per cylinder has been borrowed from aircraft engines to increase the

The purchaser of European speed automobiles is beginning to object to rough running and frequent reconditioning of sport-car engines. Hence the trend of newer developments in Europe follows the lead of American designers, the tendency being to increase the bore and the number of cylinders of speed cars to obtain flexibility on high gear.

Flexibility is solely a matter of combustion control, which problem is intensified by any increase in speed range or cylinder capacity and multiplicity. Conversion of liquid motor-fuel into a gaseous state is prerequisite for the clean and controllable combustion that gives engine rhythm. Obviously, any scheme of combustion control as applied to automobile engines cannot be a complete system without coordination of carburetion control, or stabilization of gasoline-air mixture to assure even distribution, along with combustion control or timed burning of the charge. The evolution of highly
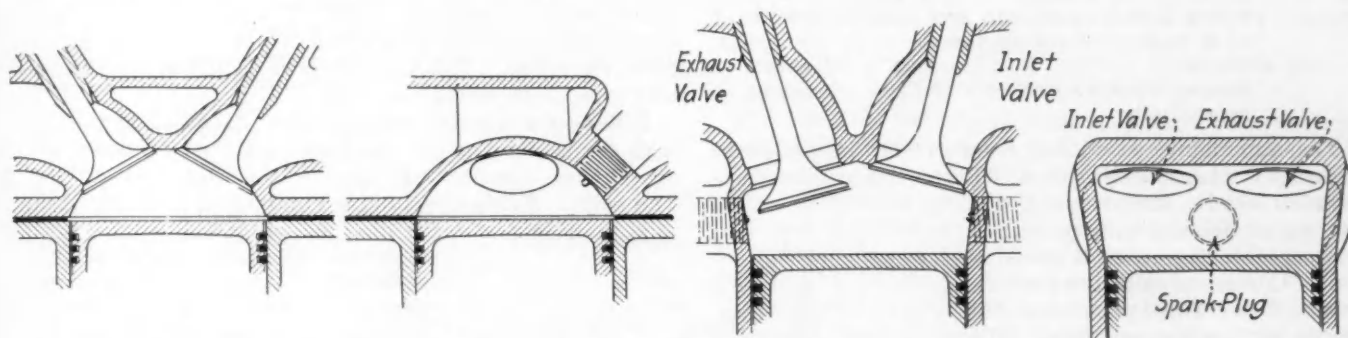

FIG. 23—OTHER APPLICATIONS OF SPECIAL COMBUSTION-CHAMBER HEADS TO HIGH-SPEED FOUR-CYLINDER ENGINES

Pertinent Data on the Engines Are Tabulated Below

Type of Head	Hemispherical	Four-Valve
Power, hp. per liter	30.7	26.8
Power, hp. per cu. in.	0.5031	0.4392
Bore, mm.	72	100
Bore, in.	2.83	3.94
Stroke, mm.	120	140
Stroke, in.	4.72	5.51
Piston Displacement, liters	1.954	4.398
Piston Displacement, cu. in.	119	268
Compression Ratio	...	5.5 to 1
Maximum Power, b.hp.	60	118
Speed at Which Maximum Power Was Developed, r.p.m.	4,250	3,500
Maximum Brake Mean Effective Pressure, lb. per sq. in.	112	...
Speed at Which Maximum Brake Mean Effective Pressure Was Developed, r.p.m.	2,000	...
Brake Mean Effective Pressure at Maximum Power, lb. per sq. in.	96	...

volumetric efficiency of the engine. The gain is more apparent, owing to increase in the number of valves per cylinder, than real as represented by increased pumping capacity. The fact that simpler engines often give a better performance is rather bewildering to the engine designer who does not study streamline flow and flow interference.

The drawing at the right of Fig. 23 represents an overhead-valve engine with four valves per cylinder. This has been used with great success in long-distance racing competitions for sport cars that can be purchased by the public. The compression ratio of 5.5 to 1 is higher than that of standard engines. The lobular pockets around the exhaust valves become detonative heat-traps with this compression, and gasoline containing benzol or other dope must be used to prevent knocking.

Fig. 7 gives power curves from two British sport cars having engines of the highest repute. Evidently the extra valves of the four-valve-per-cylinder engine are redundant as compared with a two-valve-per-cylinder head giving a greater power output per liter.

efficient but docile engines demands superspraying of fuel and perfect saturation of air with gasoline vapor, besides directed flow in filling and burning.

Whatmough Principles of Combustion Control

A new standard of engine performance definitely accrues from the coordinated application of Whatmough principles. These can be summarized in simple sequence as heating, flow and cooling effects, and are as follows:

Heating Effects

(1) Heat in air intake is automatically proportioned to fuel metered. This is essential for flexibility and flash acceleration.

(2) Available heat in air is arranged in accordance with mean fuel-volatility to produce a saturated or stable mixture. This is essential for volumetric efficiency and fuel efficiency.

(3) Warming of wet charge over exhaust valve produces a dry mixture for ignition. It lessens initial lag and uneven running on light load (see Fig. 2).

(4) Warming of clearance space to stop flame quenching and fuel waste (see Fig. 4).

Flow Effects

(5) Streamlining of intake increases effective portway during induction. It gives greater power-output with smaller valves and valve lifts.

(6) Streamlining of transfer passage increases flow into cylinder. It removes internal restriction on volumetric efficiency and prevents side thrust of flame on piston.

(7) Streamlining the exhaust passages increases useful compression-ratio by minimizing turbulent heating (see Fig. 5).

(8) Directional firing smooths burning (see Fig. 3). It also burns combustible most likely to ignite spontaneously before dangerous pressure-rise leading to auto-ignition and engine knock.

Cooling Effects

(9) Lateral location of exhaust-valve cavity to give extra cooling surface. This prevents auto-ignition in this heat trap and permits the use of a higher compression-ratio.

(10) Differential cooling, to counteract zonal effects tending to auto-ignition and flame quenching respectively.

The automobile world has been greatly intrigued in regard to what constitutes a Whatmough combustion-chamber head. The answer is that no such thing exists *per se*, as Whatmough principles concern the engine as a working unit. Compared with the embodiment of working principles, the shape and arrangement of individual parts of the combustion-chamber head are merely secondary and usually any modern type can be modified to meet trade requirements. However, the form of the head limits the ultimate power-output according to its pumping capacity or the volume of charge induced.

Carburetion control and mixture stabilization permits a greater power-output and a wider range of engine speeds when combined with combustion-chambers freed from internal restrictions. Such increase in the breathing capacity of the engine entails in turn a need for correcting the heat exchanges between the compressed charge and the hotter or colder walls of the combustion-chamber, as otherwise the desired smoothness of burning is lost.

The successive stages of development of Whatmough heads concern harmonizing combustion with fuel characteristics such as volatility and ignitability instead of compromising thereon as hitherto. The practicability of the principles has been proved beyond doubt.

A Super-Efficiency Combustion-Chamber Head

A futurist design is included to show how destructive heating can be overcome and the way cleared to a still wider range of engine speeds. Fig. 24 depicts a design of combustion-chamber head requiring mixture control and compensatory circulation of water as essential preliminaries to its working application. A glance at the drawing will show that the first feature of note concerns the use of a relatively large gallery induction-pipe acting as a reservoir of stabilized fuel-air mixture. The pumping capacity of the engine is increased by this expansion chamber damping out fluctuations and reversals during engine suction. The inlet port takes the form of a curved venturiform annulus as the inlet valve opens, which type of aperture gives a greater flow and also lessens the effect of varying suction during sudden opening and closing of the valve. The real object of the curvature of the intake into the cylinder-head is to divert the gas-flow into the cylinder, as shown by the dash lines. An ordinary mushroom-head poppet-valve causes violent eddying at high speeds, owing to the mixture being directed on to the cylinder-walls. Flow measurements show that a gallery pipe with a venturiform valve-port increases the orifice coefficient by about 40 per cent, but the all-important consideration is that the new type of intake permits excellent volumetric efficiency with a lower valve-lift. The latter may be from 6 to 8 mm. (0.236 to 0.315 in.) which is another aid to noise reduction. The cylinder-head is of the anti-turbulent type, with lateral ignition.

Differential water-cooling is also embodied in the design to assure smooth burning and fuel efficiency by preventing overheating and overcooling respectively. The water circulation in the combustion-chamber head
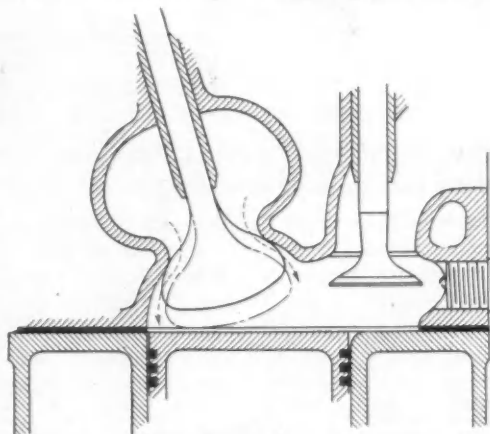

FIG. 24—A SUPER-EFFICIENCY COMBUSTION-CHAMBER HEAD

Details of the Cylinder with Which This Head Was Used Are as Follows: Bore, 73.5 Mm. (2.89 In.); Stroke, 105 Mm. (4.13 in.); Piston Displacement, 3.564 Liters (217 Cu. In.) and Compression Ratio, 6.25 to 1

is divided into two parts with separate outlets controlled thermostatically. The cooling water enters at the exhaust side and passes around the exhaust valve-seat and spark-plug boss. Recirculation by pump within the engine occurs until the thermostat opens at 70 deg. cent. (158 deg. fahr.), when the hot water passes to the radiator. At the induction side the water stagnates until the thermostat in the separate water-header opens at 85 deg. cent. (185 deg. fahr.), when hot water from the exhaust side passes thereto via the cylinder jacket and large ports at the hot side of the cylinder-head.

The aim of this engine simplifies into cooling the heated exhaust-valve cavity in proportion to engine speed and independently heating the induction system with relatively stagnant hot water. The final result is a virtual separation of the intake and exhaust sides of the head, as in the simplest early form of combustion-chamber, the T-head. The difference is that all parts are arranged to the best advantage. The intake is now warmed and mixture flows directly into the cylinder. The exhaust-valve cavity consists of a compact combustion-chamber arranged laterally to limit intensive cooling to this part only.

The control of flame propagation in automobile engineering practice simplifies into heat being abstracted to reduce the rate of flame travel or heat being added to increase flame speed. However, this redressing of the heat balance is easier to point out than to carry out. The correctional means to prevent overheating and overcooling appear contradictory from a conventional view-

point, but the innovations in combustion-chamber design are not so perverse as they seem from first impressions. Actually they constitute the simplest possible precautions against the disastrous sequelae of building up an adverse heat-balance that may end either in auto-ignition or in flame quenching.

The examples prove that convention can be cast aside when it interferes with the steady succession of events leading to the smooth burning that assures even propulsion during each working stroke of an automobile engine. Most of these combustion-chamber heads are contrary to accepted practice. The flattest L-head (Fig. 21) gives sufficient power output for a sport-car engine. Again, the longest flame travel occurs in a super-compression engine (Fig. 5). Spark-plug location at the hottest part of the head has always been condemned.

Compactness, turbulence and central ignition are postulates from heat theory which have become traditions in combustion-chamber design. Contrast therewith working principles of combustion that convert over-hot and over-cool mischief makers into trouble savers. Illustrative comparisons of theoretical assumption with experimental evidence are given in Table 2.

TABLE 2—COMPARISONS OF THEORY WITH PRACTICE IN COM-
BUSTION-CHAMBER DESIGN

Theory	Practice
Compact combustion-chambers are more efficient owing to smaller heat-loss	*Compact combustion-chambers* are usually overheated or overcooled
Turbulent heads assist flame propagation but are antiknock in action	*Turbulent heating* is the prime cause of overheating and consequent detonative combustion
Central ignition is ideal for power and antiknock	*Lateral ignition* obviates knock and permits higher compressions which give greater power-output

The failure of theory is due to generalizing, whereas success in practice follows taking advantage of the differential distribution of heat to and from the walls of the combustion-chamber and using such relatively hot or cold zones to accelerate or retard combustion as and when required.

Industrial Success

Success or failure in the automobile industry depends ultimately upon the extent to which current demands are met, and their diversity and divergence in order of importance may be exemplified by extremes, as given in

TABLE 3—QUALITIES IN COMMERCIAL VEHICLES AND HIGH-
GRADE PASSENGER-CARS ARRANGED IN THE ORDER OF THEIR
RELATIVE IMPORTANCE

Quality	Commercial Vehicles	High-Grade Passenger-Cars
1	Service	Flexibility
2	Economy	Smoothness
3	Power	Power
4	Smoothness	Service
5	Flexibility	Economy

Table 3. Buyers are prepared to pay for their preference in the two classes shown, but sales of production motor-cars require the best all-round compromise possible at the market price.

The discrepancy between objective and achievement is striking and typical of the contrariness of uncontrolled combustion. The commercial engine must run hot to stop fuel waste but overheating is detrimental to maintenance in service, the most important criterion of all. Conversely, the high-grade passenger-car is over-engined and so cool that the desired flexibility is missing when it is most wanted at low speeds.

Combustion Control

All the five desirables given in Table 3 accrue from combustion control, which is far more than combustion-chamber design even in its widest sense as engine design. Flexibility is largely a question of fuel subdivision and distribution in the pre-combustion stage, and smoothness is a matter of regulation of heat exchanges during the burning of the combustible.

A symposium rather than a single paper would be necessary to deal adequately with the subject in all its linked complexities. The Combustion Session, Mixture-Distribution Conference and Research Session are dealing separately with aspects of the problem of combustion control that cannot be separated in engine practice. The unifying factor is heat control.

The effect of the surroundings must be coordinated in any complete scheme of combustion control. Roughness or rhythm can be produced by modifying the direction of heat-flow during combustion, while flatness or flexibility follows the direction of heat exchange during induction, being flat if condensing fuel and flexible when gasoline remains vaporized. Systematic balancing of heat-flows is the basis of control of carburetion, distribution and combustion. The simplicity of this working principle is as amazing as the incredibly smooth propulsion resulting from controlled combustion.

Economics of the Chevrolet Engine

By ALEX TAUB[1]

SIX CYLINDERS are used in the Chevrolet engine, because six cylinders give smoother action and a longer range of satisfactory performance than four. Maximum results per dollar has been the ideal in the design, and high output has been secured at a cost very little higher than for a four-cylinder engine.

The piston displacement is large enough to give satisfactory performance without fine tuning. The bore is made as large as possible within the space required for water-cooling around the valves. The stroke is short, resulting in low inertia forces and a stiff crankshaft with the minimum amount of metal. Three main bearings are found sufficient, because of the stiffness of the shaft and the inherent balance of the groups of three cylinders.

Positive lubrication is provided, without pressure. The overhead-valve mechanism is so proportioned and the cooling of the parts is so arranged that variations in expansion cancel each other and result in nearly constant valve clearance. The combustion-chamber represents an advanced application of the thermodynamic principles of combustion control.

Differences of opinion are freely expressed in the discussion. The splash lubrication is questioned by several, but is defended by Chairman Round. Mr. Taub explains that the use of pressure lubrication is almost impossible, in big volume production, without an automatic method for cleaning the drilled oil-holes, and says that stroboscopic study shows two injections of oil per revolution into the connecting-rod bearings.

Other features that come in for questioning are the three-bearing crankshaft, the three-port inlet-manifold and the possibility of steam-cooling. Mr. Taub shows that the crankshaft adopted gives the maximum in value per dollar, and reports creditable wear tests. The basis of automobile taxation in Europe is said to dictate the small bore and to be an effective defence against the importation of American cars. Mr. Taub illustrates the better distribution secured by a three-port than by a four-port inlet-manifold.

BASIC economies are of necessity involved in the evolution of a low-priced product, particularly in a competitive market such as exists in any price class in the automobile industry. A major fundamental requirement for maximum production economy is sustained volume, without which there is no beginning; and sustained volume is a sort of public award in the form of a wide acceptance of the product. This is the resultant of a deliberate meeting of a demand before the demand has crystalized; in fact, it is crystalizing public demand in your own product.

There was a time when price alone, the dollar, was depended upon to obtain user appreciation; now it is result per dollar. Price class establishes the dollar, but price does not establish quality, performance or durability, which are the quantitative measurements of the result. Therefore, a powerplant, particularly in the low-price range, must represent a true picture of utility per dollar to both user and manufacturer. For the user, it must represent progress and be capable of delivering power over the greatest period for the minimum upkeep and with minimum physical disturbance. For the manufacturer, it must be capable of being produced to satisfy under volume production, with a maximum inherent facility for foundry, forge, machine-shop and assembly; also it must be easy to produce good.

To produce this maximum utility per dollar to user and manufacturer is the aim of every organization. Such a result presupposes an understanding of the ingredients of the result. We must be capable of visualizing or appreciating an ideal in order to attain it.

When the effort is made to increase the utility of the product, it is necessary to obtain the benefit of the suggestions of all who are capable of constructive thought. Thus are brought together the sales organization, with its public contact and field experience; the manufacturing department, with its ideas for facilitating production; and the engineering department, with its technical ideals and performance requirements.

Does the new product fill a need? Is it greater value per dollar? Will it be definitely better than the current models? Can it be produced in maximum volume? Is it easy to produce good? If it fails to measure up to these demands, it will not pass. A development program is a program of determining and anticipating the future demand and trend.

The future is a shifting panorama; therefore the design to meet it must be kept liquid up to the time of delivery to the production department. But a program cannot be entirely liquid; hence its fundamentals must be based on sound facts. It is essential that, when needed, a finished product shall be ready. The Chevrolet powerplant was born of such a program, and it has been developed and adjusted to fit the basic requirements of its price class. The determination of its fundamentals can best be brought out by an intimate description of how the Chevrolet engineering organization proceeds.

Four Cylinders or Six?

Perhaps the first question that must be answered is, Why a six in the price range of the Chevrolet? It was seen that the future demanded improved smoothness and performance with greater durability. It was also foreseen that "big-car appearance" would be in demand.

Improved performance includes higher maximum speed, greater acceleration and better hill-climbing ability. Greater durability includes longer life for all bearing surfaces; also a longer period of gas-tightness for the valves is necessary for sustained performance. It is needless to discuss the inherent vibration of the

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four-cylinder engine. We have been through a long program of harmonizers, dampeners and engine mountings; and the result has always been increased complication, or else the relief was only temporary. Aluminum pistons have modified the difficulty but have not eliminated it. No unit of the car is free from the ill effects of this vibration. For this reason, in making indoor tests of chassis parts to be used with a four-cylinder engine, it is necessary to include vibration with any other motion used, to make break-down tests check with road tests.

It was logical to assume, from the facts at hand, that increased life for all parts would ensue if vibration were not a factor, and it was logical to turn to the six-cylinder engine, since this type is free from the destructive and annoying secondary forces that are the major source of vibration in a four-cylinder engine.

To increase the performance throughout the life of an engine, we are satisfied that it is necessary to increase the piston displacement. The gains made by this method are imperishable. Increasing the piston displacement of a four-cylinder engine seemed to lead to difficulty. The amplitude of the vibrations was increased, both in direct drive and in coasting. Besides this, the increased bulk of the charge per cylinder would increase the explosion reactions. Although we are able to control combustion to some extent, the four-cylinder charge was already large and difficult to control thermodynamically. Improvement could be made by stiffening the engine and the chassis, but the increased weight and cost would make the powerplant economically unsound for our price range; the result per dollar would be questionable.

Bulk of Charge Must Be Limited

Logically, for increased performance, we turned to the six, since this type of engine, having a smaller bulk charge, lends itself to thermodynamic exploitation. The six-cylinder engine has much elbow-room for expansion as to over-all size. The difference in weight and cost between a satisfactory 170-cu. in. six and a satisfactory 200-cu. in. six would be a great deal less than the difference between satisfactory fours of the same displacements, assuming equivalent final results.

We must have in mind, further, that performance at low car-speed is a necessary requisite, so a high power-output is required at low engine-speeds. Assuming for the moment that the four-cylinder engine is inherently as well balanced as the six, we should still be forced to consider the violence of the torque reaction of the engine explosions when synchronized with the chassis period. The higher the car speed is at which this tuning-in occurs, the more objectionable it is, and the four would tune in at a higher car-speed than would a six, because of its fewer explosions per revolution. If the violence of the explosion is increased, either by an increase in bulk, as in the four, or by increasing the engine output on the low end, we increase the degree or amplitude of the torque reaction.

Thus it is obvious that it is possible to exploit the low-end-power possibility of the six, because its power impulse is relatively light. How this can be done advantageously is shown in Fig. 1, which compares the ranges of the curves of brake mean effective pressure of a six and two fours, both of which have seen service in the low-price field. The low-speed characteristics of the six are considerably better than those of the fours,

assuring good lugging ability and acceleration. This is secured without sacrificing performance at high speed.

The types of fours indicated here are widely different, yet their performances over the range of speeds are similar. The lower output at low speeds made them acceptable as to torque reaction, and the lower output at high speeds permitted a low-weight structure to be used that would have been inadequate had the power output been as high as indicated for the six. The six thus forces its way into consideration by its smooth operation and performance-range possibilities.

Comparison as to Cost

Cost has not advanced at the same rate as utility. The demand for "big-car appearance" has already crystalized. Artistic proportions are the order of the day, and the Chevrolet chassis was lengthened last year to provide a hood in proportion to the body length. Thus even the gods of style bow a welcome to the six, because this additional length provides the necessary space for the installation of a longer powerplant.
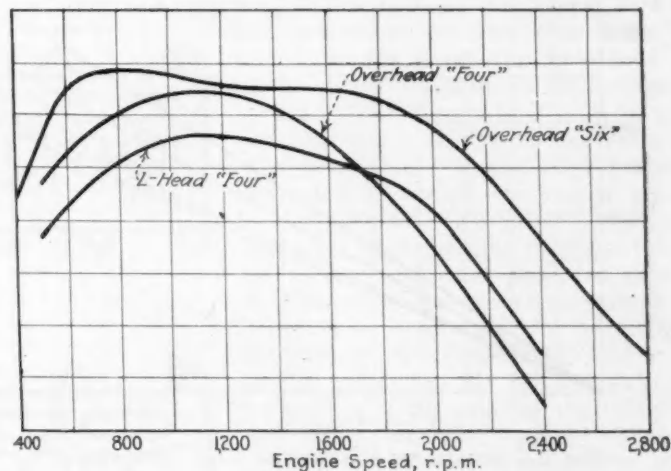
Cost as affected by the additional weight of this en-

FIG. 1—RANGE OF BRAKE MEAN EFFECTIVE PRESSURE OF THE ENGINES OF REPRESENTATIVE LOW-PRICED CARS

gine has been controlled by careful consideration of metal distribution. Reduction in weight is the most difficult project that an engineering department can undertake; however, improved performance can be had only by a reduction in weight-power ratio; and we must not increase weight and power in the same proportion, since the cost will be raised with no increase in utility.

The cylinder-block usually receives the most consideration as the major part of the total weight. However, it does not offer much opportunity for saving unless low weight is a fundamental consideration in the design. Light unsupported walls are a constant source of trouble from warpage under heat and in the finished product because of deflection and resonance. Therefore walls in a cylinder-block should be supported or be short or thick enough to prevent these troubles. Obviously, short walls of medium thickness will give the lightest satisfactory construction.

Machineability is the problem in the machine-shop. The block must be sufficiently rugged to permit accurate and fairly rapid machining, and this may require greater rigidity than is necessary in the finished product. If accuracy cannot be maintained, the construction must be changed or weight must be added.

Other problems are met in the foundry. Iron at the cupola spigot may cost 2 cents per pound, yet the final-casting cost may be 4 to 7 cents per pound. The difference is the labor and burden involved in molding, cleaning castings, and scrap. If the walls are too thin to cast with the minimum scrap, there is a saving in weight but probably an increase in cost. If the molding is complicated, the cost is increased without any gain except in scrap hazard. If weight is added in a way to simplify molding and reduce the possibility of scrap, it can be added for little or no cost. At least, when metal is added, it should be done without any effect on the operations between the cupola and the final casting, so that it can be added at cupola price.

This general principle of metal-cost distribution has been carefully considered in all parts of the Chevrolet

TABLE 1—COMPARISON OF PERFORMANCE FACTORS

	Piston Displacement				Compression Ratio	Engine Speed, R.P.M. per M.P.H.	Piston Velocity, Ft. per Car-Mile
	Cu. In.	Cu. Ft. per Ton-Mile	Cu. Ft. per Car-Mile	Axle Ratio			
A, Six-Cylinder	160.3	109.0	179.3	5.60-1	5.75:1	64.42	2,899
B, Four-Cylinder	200.5	104.6	152.9	3.77-1	4.40:1	44.00	1,867
C, Six-Cylinder	176.3	105.0	167.7	4.56-1	5.10:1	54.17	2,099
Chevrolet Six	194.0	100-104	154.1	3.80-1	5.00:1	45.80	1,717

FIG. 2—DURABILITY FACTORS OF CARS COMPARED

Factors of the Three Cars of Fig. 1 and the New Chevrolet Are Compared

powerplant, and by its application we have been able to improve utility greatly and cost only slightly.

Determination of Piston Displacement

Bearing in mind that we are considering an increase in utility or result, we must consider an increase in performance. Since we are dealing with a six, it is possible to consider a considerable increase in piston displacement before the explosion or torque reactions would become objectionable. Further, piston displacement increases more rapidly in a six than in a four for a given dimensional change. Therefore it is possible to make an appreciable change in size without materially affecting the cost.

The desired performance could be obtained with a relatively small engine of high efficiency or with a larger engine of moderate efficiency. With the former, the desired performance could be obtained only when the engine was in tune. With a larger engine, we are assured of maximum performance for the greatest number of car miles, since the major factor in its performance—displacement—is non-shrinkable, and a reasonable efficiency is not difficult to maintain.

In determining piston displacement, we are accus-

tomed to use a performance factor based on cubic feet per ton-mile. This eliminates all factors except direct dimensional and mechanical ratios such as piston displacement, weight, axle ratio, and revolutions per mile of the rear wheels. Such a factor is adequate, provided it is backed up by road data as to the qualitative results to be expected. This presupposes at least average efficiency. Should the engine efficiency fall below the average, the actual performance is below the expected; and should the efficiency be above, then all is well.

It would seem from this that all that is needed is to set the performance factor higher than in competing cars. However, there is still the economy factor to consider, which is the nominal number of cubic feet of air and fuel pumped through the engine per mile. If economy is to be considered, we must keep the performance factor within reasonable bounds. This is usually determined in a proposed design by comparing various combinations of the major items.

Performance and Durability Factors Compared

Performance factors of three cars are compared in the first three lines of Table 1. A, which is a six, has a high performance-factor of 109 cu. ft. per ton-mile, but this is obtained by an axle ratio of 5.6 to 1 and a relatively small engine. The number of cubic feet per car-mile is likewise high, 179.3, denoting bad potential economy. An effort is made to overcome this handicap by a compression ratio of 5.75 to 1. This combination is evidently intended to be a high-speed, high-efficiency, small engine, and the price paid is indicated in the last two columns by the piston velocity of 2899 ft. per car-mile and the engine speed of 64.42 r.p.m. per m.p.h.

The car designated B has a good performance factor of 104.6, obtained with an axle ratio of 3.77 to 1. The engine is relatively large, yet the economy factor of 153 cu. ft. per car-mile is very reasonable. However, the 4.4:1 compression-ratio is low. The advantage in durability, of this combination of large, low-efficiency engine and high axle-ratio, is indicated by the piston velocity of 1867 ft. per car-mile and the engine speed of 44 r.p.m. per m.p.h.

The car designated C is a compromise giving a good performance factor of 105, obtained with a rear-axle ratio of 4.56 to 1. This car has a medium-sized engine and medium axle-ratio. The attempted efficiency is reasonable, as indicated by this 5.1:1 compression-ratio; but the economy factor of 167.7 is not low. This compromise has not much to offer in potential durability, as represented by the piston velocity of nearly 2100 ft. per car-mile and engine speed of 54 r.p.m. per m.p.h.

These combinations indicate the wide range of variations that exist in present practice and in engineering opinion.

The revolutions per minute per car-mile of these cars are charted in Fig. 2. The comparison of the

speeds of these engines is very significant in view of the present speeds of low-priced cars. Speeds such as indicated in line *A* cause dangerously high internal stresses and loads and require extreme care as to lubrication, both in design and in ordinary service. Curve *B* looks rational and obviously represents no great hardship in maintenance. Curve *C* is fairly high but certainly not too high.

The bottom line in Table 1 indicates the performance and durability factors of the Chevrolet powerplant. The performance factor is 100 to 104 cu. ft. per ton-mile, according to the type of body. The axle ratio of 3.80 to 1 gives an economy factor of 154 cu. ft. per mile and durability factors of about 46 r.p.m. per m.p.h. and 1717 ft. piston velocity per car-mile. The attempted efficiency, as represented by the compression ratio of 5 to 1, is reasonable. The relative positions of the durability factors of this car are indicated in Fig. 2. Obviously, the factors selected represent good practice.

An interesting side-light is that car *A* has a lower actual performance than any of the other three. It

[2] See S.A.E. JOURNAL, March, 1929, p. 282.

FIG. 4—WATER-JACKET CORE FOR CHEVROLET CYLINDER-BLOCK
This Core Is Molded in One Piece, Instead of Being Made of Two Parts Pasted Together Along the Engine Center-Line

seems that the efficiency of this powerplant must be low, as its potential performance factor is the highest.

Bore, Stroke and Engine Length

Desirability of a Large-Bore Engine[2] is the subject of a paper that I read at the Annual Meeting of the Society in 1929. In it the conclusions were reached that the valve sizes are determined by the piston displacement, speed range and performance required of the engine; that water-cooling must be provided between adjacent valve-seats and between adjacent cylinders; and that the most economical bore is the largest that can be used in the length as determined by the foregoing considerations. A section through an engine such as those shown in Fig. 3 is a sufficient basis for the whole story of a powerplant. If the valve seats are not fully cooled, the valves will be undercooled. This usually means expensive heat-resisting material for the valves; and what good can this do if the valve-seat warps, as it must if provision is not made for uniform expansion? A temperature difference of approximately 300 deg. fahr. between opposite sides of the valve-seat will necessitate frequent valve-grinding and denote unreliability of performance, with a pronounced "tired" feeling after hard driving.

The lower section in Fig. 3 is through the cylinders of the Chevrolet engine. Water-cooling is provided entirely around the cylinder and valve-seats. The bore, determined as indicated in the foregoing, is 3 5/16 in., making the stroke 3¾ in. to secure a piston displacement of 194 cu. in. The result is an engine having length enough to provide space for all important engine fundamentals.

Fig. 4 represents an interesting piece of foundry work developed to obtain positive assurance that water will completely surround the barrels. This sketch is of the water-jacket core that is made in one piece, the core box being open at the top. The usual practice is to split this core on the center-line of the cylinders, making a joint at the thinnest part of the core and causing fins in the casting where they are most harmful.

FIG. 3—ENGINE SECTIONS SHOWING PROVISION FOR WATER-COOLING
The Upper Section, Through the Chevrolet Cylinder-Head, Shows Provision for Water-Cooling Entirely Around the Ports. The Oblong Openings Show the Cut Through the Folded-Up Portion of the Combustion-Chamber. The Ports Are Crowded Closer Together in the Shorter Section. The Two Small Vertical Sections Show the Difference in Length of Valve-Stem Bosses, Designed To Equalize Valve-Gear Expansion in the Chevrolet Engine. The Bottom Section Shows How the Water Completely Surrounds the Cylinder Barrels of the Chevrolet Engine

The ideal crankshaft incorporates the maximum rigidity, the highest period-position, and the minimum period-duration for the fewest pounds of steel.

Principles outlined in the paper on large-bore engines[2], to which reference has been made, were followed in the design of this crankshaft. With the relatively large bore, it is possible to use a large crankpin without preventing the removal of the piston and connecting-rod upward, through the cylinder-bore. The crankshaft has three main bearings, as shown in the view of the bottom of the engine, Fig. 5. Fig. 6 is a detail, showing how the crankpin overlaps the main bearing.

Number of Main Bearings

There has been considerable controversy as to the number of bearings that should support a six-cylinder crankshaft. The early use of three-bearing six-throw crankshafts was with long-stroke engines and/or the crankshafts were light. It was known then, as now, that the three-bearing shaft possesses the best possible balance, because the six is a combination of two three-cylinder engines, each inherently balanced.

Some manufacturers thought it necessary to add another bearing to support their relatively flexible shafts, and thus the four-bearing shaft became the vogue. However, difficulties continued. It was found impossible to obtain reasonable field life for the intermediate bearings, since the balance was *through* the bearings instead of between them. The shafts were increased in size to offset the abnormal wear resulting; but little good was accomplished, because the increased rotating weight kept pace with the increased bearing surface.

Seven bearings were next adopted, by some, to overcome the evil. This gave ideal support but increased the torsional flexibility, since the shafts were made as light as possible in an effort to reduce the additional cost. But seven bearings were more difficult than four or three to align, and this difficulty was particularly manifest in a difference in alignment between hot and cold conditions. One manufacturer in the highest-price class fitted the four intermediate bearings of his seven-

[2] See S.A.E. JOURNAL, March, 1929, p. 282.

bearing crankshaft loosely to allow for this condition, thus making seven supports but only three bearings.

In the meantime, the proponent of the four-bearing shaft adopted counterweights as a means of eliminating excessive bearing wear, which they accomplished. However, the weights served to bring the torsional-vibration period down into the driving range; and this has brought on the present harvest of dampeners, harmonizers and balancers. The result-per-dollar principle was lost sight of entirely.

Concentrating the rotating weights as near the center of the crankshaft as possible reduces the resultant bearing loads and enhances the rigidity. Rigidity is aided also by the overlapping of the main bearing and the crankpin, because the "accordion" action of the shaft is eliminated.

FIG. 6—DETAIL SHOWING OVERLAPPING CRANKPIN AND MAIN BEARING AT SHORT ARM OF CHEVROLET CRANKSHAFT

By careful consideration of all design factors, a three-bearing crankshaft was developed that incorporates inherent rigidity, inherent balance betw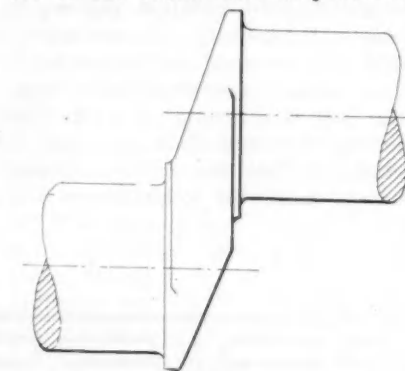een bearings, low bearing-loads, low piston-velocity, and torsional vibration only beyond the driving range. Combined with the simplicity of a three-bearing crankcase, this design gives an outstanding example of result per dollar.

Bearing Loads and Fiber Stresses

Examination of the bearing loads, as listed in Table 2, is interesting because they are so low. The loads vary from 310 to 676 lb. per sq. in. at 3000 r.p.m., corresponding to a car speed of 65 m.p.h. The data in this
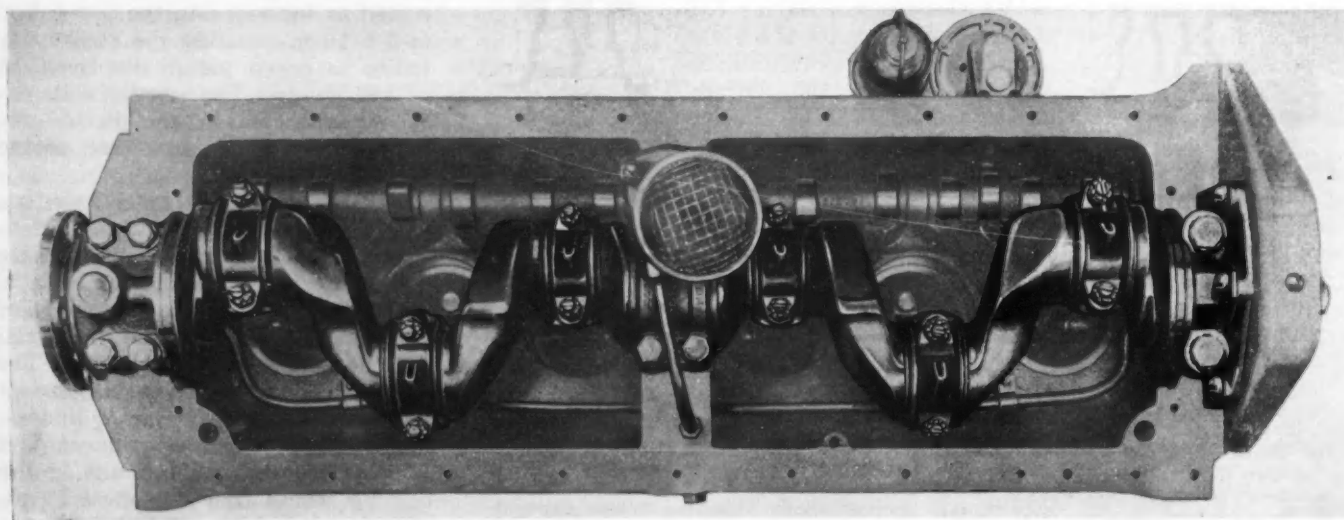
FIG. 5—CRANKSHAFT IN PLACE IN CHEVROLET ENGINE
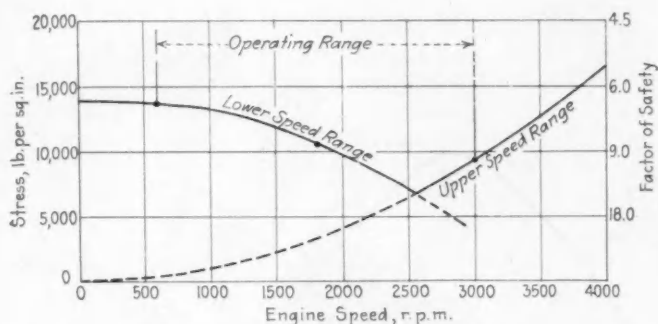
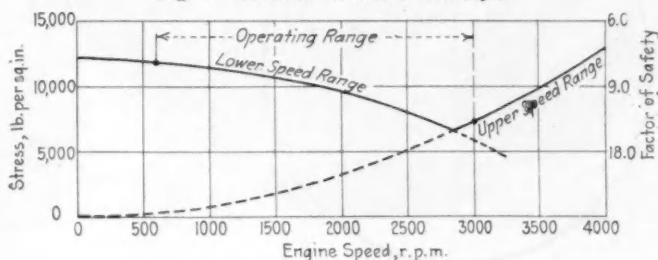Fig. 7—Stresses in No. 5 Crankpin

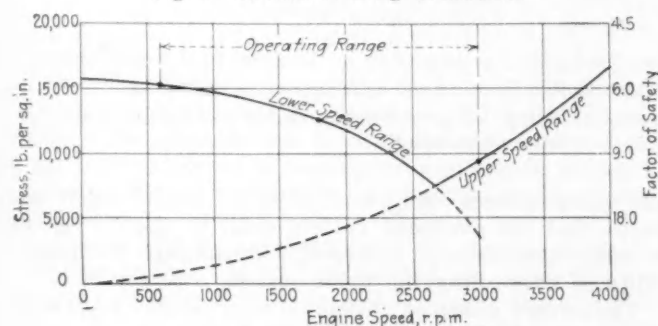
Fig. 8—Stresses in Long Crank-Arm

Fig. 9—Stresses in Short Arm

STRESSES IN THE CRANKSHAFT DUE TO UNBALANCED EXPLO-
SION FORCE AND TO INERTIA AND CENTRIFUGAL FORCE
Factors of Safety Are Shown at the Right of Each Chart

TABLE 2—AVERAGE PRESSURE ON ENGINE BEARINGS AT VARIOUS
ENGINE-SPEEDS

Bearing	Projected Area, Sq. In.	Revolutions per Minute		
		600	1,800	3,000
		Bearing Pressure, Lb. per Sq. In.		
Connecting-Rod	2.75	138	251	524
Front Main	3.43	155	219	405
Rear Main	4.48	118	155	310
Center Main	4.00	264	325	676

point in a crankshaft. The maximum stress, at 600 r.p.m., indicates a factor of safety of about 5 to 1. The stress at this point also decreases with speed, the low point being at 2675 r.p.m. or 58 m.p.h.

The point of most interest in Figs. 7, 8 and 9 is that the stress is low at high speeds. The curve from 600 r.p.m. to the point of lowest stress represents the un-absorbed explosion-force, which decreases with speed. The curve from the lowest-stress point upward on the speed range represents the reciprocating and centrifugal forces at top dead-center of the exhaust stroke, which increase over the entire speed range. If that portion of the curve made up of centrifugal and reciprocating loadings were higher, as it would be if the stroke were longer, the stresses would be much greater at high car-speeds.

This crankshaft is an outstanding example of utility per dollar. It represents the maximum rigidity per pound of steel of any used in the industry today; further, it distributes the explosive and dynamic loads on its bearings at extremely low unit pressures and, finally, the internal stresses are lowest at high car-speeds. Thus it satisfies the engineer. In the machine-shop, the inherent stiffness of the shaft facilitates accurate and rapid handling through its machining and grinding; hence it satisfies the manufacturing department. The forge shop naturally is satisfied with this simple short-throw shaft, which can be forged with the pins in index.

Positive Lubrication Without Pressure

Sure lubrication of all parts is necessary in order to realize on the road the durability indicated in the foregoing. To this end, distribution of oil to all necessary

table were determined from polar diagrams and include loads due to pressure on the piston, inertia, and centrifugal force. The low bearing-loading is due largely to the low inertia and low centrifugal-force caused by the short stroke.

The stress diagrams, Figs. 7, 8 and 9, also give unusual information. Fig. 7, showing the fiber stresses in No. 5 crankpin, indicates that the maximum stress, at 600 r.p.m. with full torque, leaves a factor of safety of more than 5 to 1. The stress decreases with the speed and is lowest at 2550 r.p.m., corresponding to 55 m.p.h. Fig. 8 indicates the fiber stress in a long cheek. The maximum stress, which is at 600 r.p.m. with full torque, represents a factor of safety of more than 6 to 1. The stress here also decreases with the speed, and the minimum point is at 2800 r.p.m. or 62 m.p.h. Fig. 9 indicates the fiber stress in a short cheek, which is generally considered the weakest
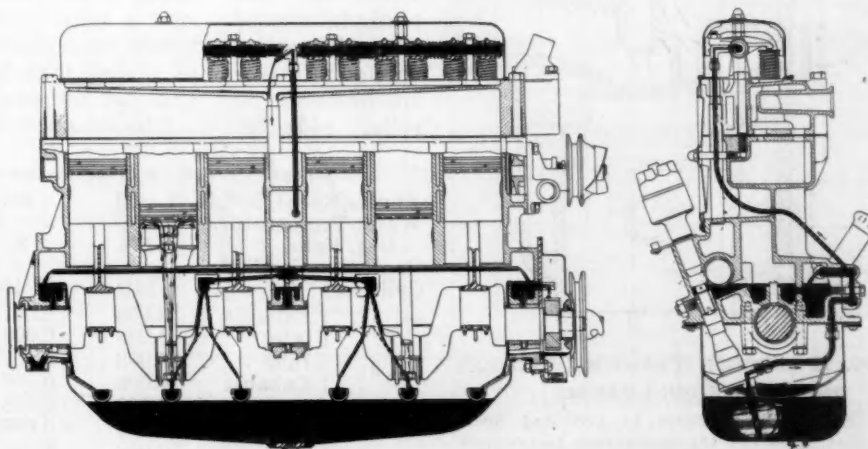

FIG. 10—LUBRICATION SYSTEM OF CHEVROLET ENGINE
Oil Is Pumped to Splash Basins and Pockets Over the Main Bearings Through
Equalizing Reservoirs. Excess Oil Goes to the Hollow Rocker-Arm Shaft To Lubri-
cate the Valve Mechanism. Scoops on the Ends of the Connecting-Rods Are Said to
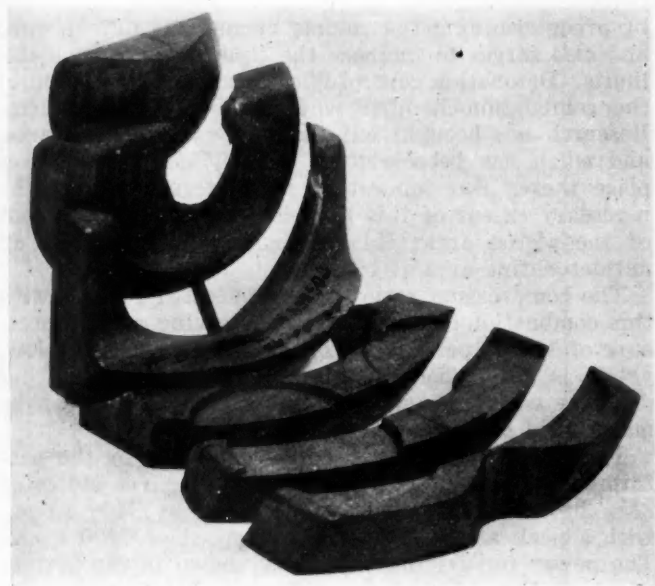Feed Oil to the Bearing Twice per Revolution

points has been provided, but not necessarily pressure at all points. Fig. 10 is a general outline of the system used. The main bearings are submerged in oil by providing pockets over the main bearings wherein the oil level is maintained above stand-pipes. The stand-pipes register with generous systems of grooves to distribute the oil in the bearings and are so located as to form sediment chambers for the collection of solids. Lubrication of the camshaft bearings is provided by making the oil level in the main-bearing pockets higher than the bottom of the camshaft bearings, with chambers leading to them.

Positive distribution of oil to each connecting-rod trough is accomplished by individual take-offs at small pressure-reservoirs which equalize the pressure for each direction. The feed to the connecting-rod bearings is by a special design of dipper that serves to force oil into the bearing in a way similar to that in which locomotives take water on the run. We have determined by stroboscopic investigation that this dipper serves also as a bucket and carries the lubricant within itself to a point on the down-stroke where inertia injects it into the rod bearing. Thus the connecting-rod bearing is served twice in every revolution.

Cam and tappet lubrication are secured by locating these parts on the throw-off side of the connecting-rod splash. Cylinder bores and piston-pins are lubricated by the rod throw-off, as is usual. The hollow valve-rocker shafts and the valve-stems are directly lubricated through a connection with the low-pressure or relief side of the oiling system. An overflow at the rocker shaft assures that the overhead system shall be filled with oil at only atmospheric pressure, eliminating the possibility of over-oiling the valve system.

Thus every phase of engine lubrication has been adequately provided for and some features are incorporated that heretofore have been considered unattainable in the low-price field.

Overhead Valves with Quiet Mechanism

The overhead type of valve gear has been retained in the new engine, because it provides high volumetric efficiency, improved manifolding and a very desirable accessibility for adjustment. This construction certainly is not favored by lowest cost, but it does represent a high utility per dollar. An organization accustomed to building this type of engine can produce it at a cost that is very reasonable, in view of its mechanical advantages.

The volumetric efficiency is better than that of other

FIG. 12—DIMENSIONED PROFILE OF A CHEVROLET INLET-CAM

Backlash in the Mechanism Is Taken Up by a Gradual Ramp Occupying 30 Deg. of the Camshaft Circle

FIG. 11—SECTION THROUGH CHEVROLET COMBUSTION-CHAMBER

A Non-Compact Form Is Provided by a Pocket, in Which the Spark-Plug Is Located. Cooling of the Last Part of the Charge To Burn Is Secured by Constricted Space at the Right. The Valve-Rocker Has Unequal Arms, Making the Actual Valve-Lift Greater than That Indicated by the Cam Profile

TABLE 3—VALVE CLEARANCES AT DIFFERENT TEMPERATURES, IN.

Engine Speed, R.P.M.		500	400	1,000	2,000	500	400
Water Temperature, Deg. Fahr.		175	82	175	177	176	90
Operating Condition		Idle	Cold	....	....	Idle	Cold
Cylinder	Valve						
No. 1	Exhaust	0.008	0.007	0.005	0.005	0.008	0.008
	Inlet	0.008	0.008	0.008	0.008	0.008	0.008
No. 2	Inlet	0.008	0.007	0.008	0.008	0.008	0.008
	Exhaust	0.008	0.008	0.006	0.006	0.008	0.008
No. 3	Exhaust	0.008	0.008	0.006	0.005	0.008	0.008
	Inlet	0.008	0.006	0.007	0.008	0.007	0.007
No. 4	Inlet	0.008	0.006	0.007	0.008	0.007	0.006
	Exhaust	0.008	0.008	0.006	0.007	0.008	0.008
No. 5	Exhaust	0.008	0.008	0.006	0.008	0.008	0.008
	Inlet	0.008	0.007	0.006	0.008	0.008	0.007
No. 6	Inlet	0.008	0.006	0.006	0.007	0.006	0.006
	Exhaust	0.008	0.007	0.006	0.005	0.007	0.008

FIG. 13—SECTIONED MODEL OF THE CHEVROLET COMBUSTION-
CHAMBER

types, because the induction passages are less tortuous.
The manifolding is improved, because the down-draft
construction prevents the accumulation of pools of gaso-
line. The accessibility is outstanding, compared with
conventional practice on L-head engines in which the
valve-adjusting mechanism is protected by the exhaust
manifold.

The most delicate question in the development of an
overhead-valve mechanism is that of noise. To over-
come this evil, it is necessary to realize the opportuni-
ties that exist in the mechanism. A rocker-arm is part
of the mechanism; and it is possible to make its arms
unequal, as shown in Fig. 11, thus materially decreas-
ing the necessary lift in the cam profile. Fig. 12, which
is an inlet cam, shows how advantage has been taken
of this construction in extremely small flank radii and

in the type and length of ramp, which are potential
anti-noise elements. Also, a generous dwell is provided
at the cam nose, which makes possible improved volu-
metric efficiency.

With a well-designed cam profile, noise can be caused
only by excessive clearance. If this clearance can be
kept constant, operation can be quiet; and constant
clearance can be secured by exploiting the compensat-
ing expansion of the valve-operating mechanism, the
valves and the cylinder-block.

Push-rod expansion is controlled by the air tempera-
ture within the side cover. This temperature can be
lowered by increasing the ventilation or raised by de-
creasing it. Cylinder-block expansion is affected by the
length of the water-jacket. The expansion of the ex-
haust and inlet-valves will react to lengthening or
shortening the valve-stem-guide bosses. Considerable
time was spent in determining the final combination.
The only visible evidence of this work may be omitted
in the difference in length of the guide bosses, as is
seen in Fig. 3.

To determine the effectiveness of the proportions
selected, all valves were set to a clearance of 0.008 in.
at 500 r.p.m., with the jacket water at 175 deg. fahr.
and no load. Clearances were rechecked at 400 r.p.m.
with the engine cold, the jacket water at 82 deg. fahr.;
at 1000 r.p.m. and water at 175 deg. fahr.; at 2000
r.p.m. and water at 177 deg. fahr., and again under
conditions approximating the original setting and cold
test. Table 3 shows that the valve clearance was in-
creased in no case, and was decreased a maximum of
0.003 in. in the case of No. 1 exhaust-valve at 1000
r.p.m., and Nos. 1, 3 and 6 exhaust-valves at 2000 r.p.m.
It is safe to say that these changes in clearances com-
pare favorably with what will be found on engines of
other types.

Combustion Controlled with Valves in Head

Combustion in an internal-combustion engine may be
more or less efficient and more or less orderly. If it is
too rapid, shock will result and the engine will be con-
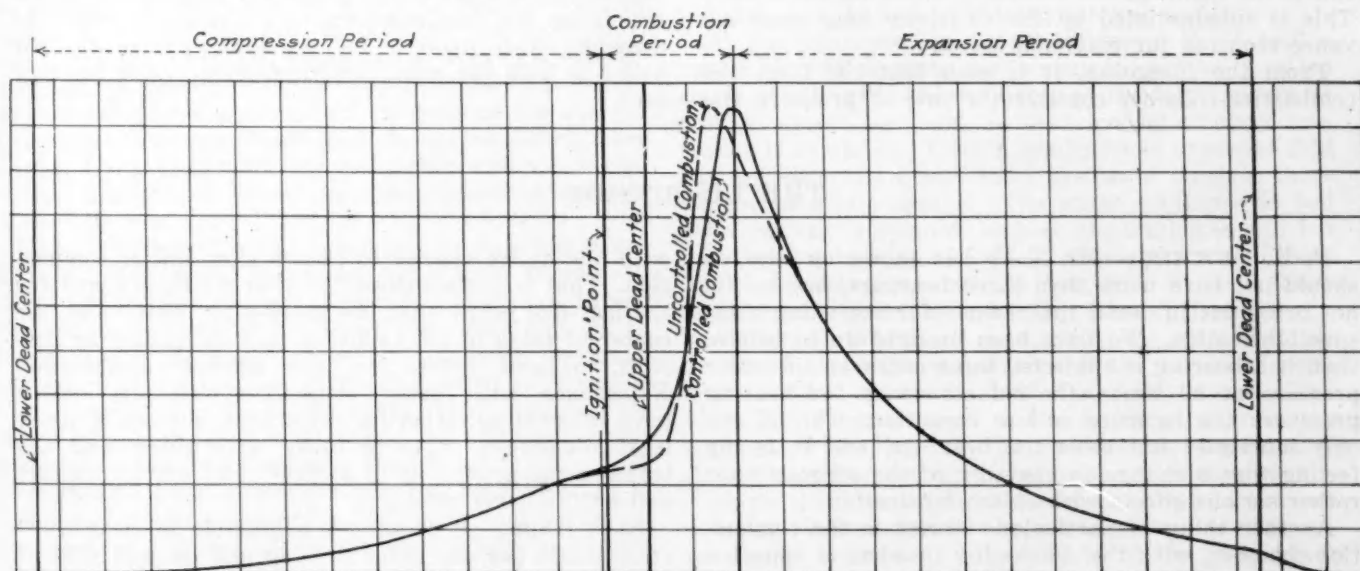
FIG. 14—PRESSURE CURVES INDICATING COMBUSTION CONTROL
The Full-Line Curve Indicates the Controlled Combustion Obtained in the Chevrolet Engine. Uncontrolled Combustion Is Charted in
the Broken Line, for Comparison

sidered rough. If it is too slow, combustion will occur late in the cycle, causing power loss and overheating of the exhaust valve, piston-head and combustion-chamber wall. This may lead to detonation and preignition. Obviously, control of some kind is required, and that can be accomplished only in the combustion-chamber.

Fig. 11 is a section of the combustion-chamber of this engine. Its shape is original, with the definite purpose of securing low-detonation and low-shock characteristics. Such an attempt presupposes a knowledge of or experience in the thermodynamics of combustion, which we have gained in collaboration with General Motors Research and other divisions of the General Motors Corp. during several years. To make intelligent progress, it was necessary to graduate from the cut-and-try methods to an accurate theoretical method of predetermination; and our laboratory physicists have furnished us with the theoretical values for explosion time and the pressures generated at various percentages of volume burned. Fig. 13 shows a model of the Chevrolet combustion-chamber in spherical sections, representing the progress of the flame front. By adding the known volume of each section progressively to the portion burned, we can predetermine the pressure-time characteristics of the combustion.

Fig. 14 shows by the full-line curve the combustion characteristic of the design under consideration. The dotted line indicates a combustion characteristic that lacks proper control. From these curves it can be seen that controlled combustion gives a considerably more gradual pressure-rise.

The right-angle form of combustion-chamber was adopted to make it non-compact. If the chamber were in one plane, it would overhang the block and make difficult the location of the spark-plug.

Explosion time is an important element in the control of roughness. Turbulence, or internal agitation, is a major factor in controlling the explosion time; the greater the disturbance the shorter is the time. If turbulence can be impeded, longer explosion-time results. As our chamber is of a tortuous shape, there can be no doubt of its retarding effect on turbulence. This is substantiated by the relatively long spark-advance required for maximum power.

From the foregoing, it is seen that the Chevrolet combustion-chamber controls the rate of pressure rise by predetermining the volume burned per unit of time and also serves to increase the time within reasonable limits. Detonation control is secured in that portion of the combustion-chamber wherein the last gas burns. Research has brought out the true value of this area, and much has been written on why detonation takes place there. Our laboratory has determined that the necessary extent of this area is from 5 to 20 per cent of the piston area; this combustion-chamber has an antidetonating area of 16 per cent.

The compression ratio we have selected for use with this combustion-chamber is 5 to 1, giving a gage pressure of 100 lb. per sq. in. This compression is not low, yet it is not sufficiently high to cause any operating difficulty with a chamber of this type; hence it can be maintained over a long period.

The efficiency actually obtained is shown by the performance curves of Fig. 15. The power curve indicates $23\frac{1}{2}$ hp. at 1000 r.p.m. and $46\frac{1}{2}$ hp. at 2400 r.p.m., with a peak at the relatively low speed of 2400 r.p.m. The power for driving the car is shown in the bottom curve of Fig. 15, and the difference between the two horsepower curves indicates the reserve for acceleration.

This chart also includes the curve of brake mean effective pressure, which is a true measure of efficiency. The maximum of this curve is $98\frac{1}{2}$ lb. per sq. in. at 800 r.p.m. This figure is high for an engine of any price class and indicates efficient operation. High brake mean effective pressure requires good volumetric efficiency, good sealing or gas-tightness, and efficient combustion; therefore, these curves are proof that the expectations of the design have been realized.

All this has been accomplished at a cost heretofore regarded as impossible in a six-cylinder engine, as a result of intensive study of the details of the design by the production department, the foundry and the forge shop; and the change from a four to a six was accomplished in a way that has been found acceptable to all departments of our organization.

This analysis is given to indicate the methodical procedure of the Chevrolet engineering department in determining the fundamentals, to enable it to meet the demands made upon it for the maximum utility per dollar to both the manufacturing organization and the user.

THE DISCUSSION

F. H. DUTCHER[3]:—Mr. Taub has shown us why we should not have more than three bearings, but he did not bring out in detail the reasons for not using pressure lubrication. We have been brought up to believe that, if a bearing is subjected to an excess of oil under pressure at all times, the old standards for bearing pressures can be more or less forgotten. The oil not only lubricates but cools the bearings, and it is my feeling that a change in viscosity of the oil may have rather serious effects with splash lubrication.

Another thing of particular interest is the combustion-chamber, with the spark-plug in what is almost a dead pocket. It looks as though this arrangement would utilize the slow burning of a mixture of exhaust gas with the active charge to secure slow initial combustion. That is quite opposed to what we have heard for the last five years, that the spark-plug must be in the center of mass to get explosion just as quickly as possible, without detonation, for efficient combustion. Experience with many combustion-chambers which have internal agitation indicates that detonation, or at least roughness, is quite likely with them, and the trend seems now to be to a little more driver comfort and a little lower efficiency.

ALEX TAUB:—It is almost impossible to clean 7000 crankshafts per day after drilling and be sure that at least 5 per cent are not left imperfectly cleaned. We have to await automatic cleaning that will assure clean shafts. We know from experience that the oil-flow through these bearings is adequate, although there is

[3] M.S.A.E.—Instructor, department of mechanical engineering, Columbia University, New York City.
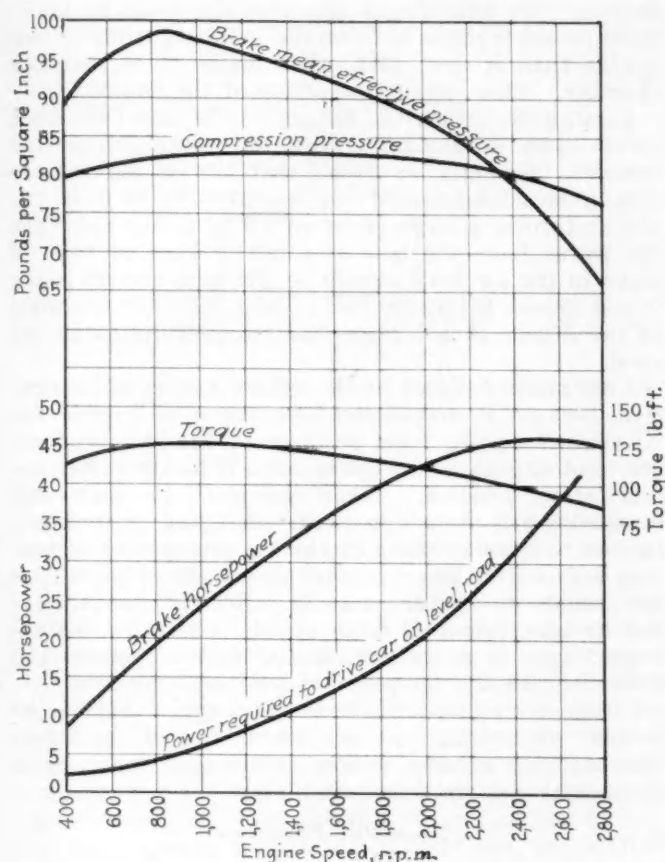
FIG. 15—PERFORMANCE CURVES OF CHEVROLET ENGINE

Curves for Brake Mean Effective Pressure, Compression, Torque, and Brake Horsepower Are Shown, also for the Power Required for Propelling the Car. An Engine Speed of 1850 R.P.M. Corresponds to a Car Speed of 40 M.P.H.

no pressure feed, because of the bearing life secured.

When this folded combustion-chamber was designed, we were dubious of our ability to obtain adequate brake m.e.p. because of the pocket effect; however, we found no difficulty in obtaining the power as indicated in the power curves in Fig. 15. In addition, we have been able to obtain up to 105 brake m.e.p. with this type of chamber. A definite relation exists between the thickness of the folded portion and the bulk of the charge. This type of chamber lends itself to volume distribution as does the L-head combustion-chamber, and we believe volume distribution to be the most important element in smooth operation.

DAVID BEECROFT[4]:—The economics of powerplant design is much more important today than it was 10 years ago, because we are exporting more than 16 per cent of our product. Exported cars generally go to places where the dollar does not buy nearly so much in automobiles as it does in this Country; yet there is that same strong desire for more motor-vehicles, because human beings are the same, no matter on what continent or in which country they live.

HERBERT CHASE[5]:—Anyone who has been disposed to criticize American designs as not being thoroughgoing engineering jobs will have an opportunity to change

his opinion after seeing what was done in developing this engine. With all due respect to the capable Chevrolet engineers, who are members of the Detroit Section, it seems to me that a prominent member of the Metropolitan Section had much to do with this design.

To what extent was the servicing considered in arriving at the design?

I am sure Mr. Taub will not take it too seriously if I enquire whether this unusual combustion-chamber was designed first and a theory found to fit it, or whether the theory was the starting point.

Mr. Taub and I both have been enthusiastic about the possibilities of steam-cooling. Was steam-cooling considered for this engine, and why was it not adopted?

Contributors to Chevrolet Engine Design

MR. TAUB:—The influence of Henry Crane can be seen in the fundamentals of both this and the Pontiac engine. I tutored under him, and I should be everlastingly grateful to him for his instruction. Undoubtedly the Pontiac and the Chevrolet engines are based upon fundamentals that he hammered home.

Fortunately, the Chevrolet service department always includes a past member of the engineering department, and for that reason the service and engineering departments are constantly working together. The head of the field service department was given this car just prior to production, and he drove it to Los Angeles and back, to get an idea of its service possibilities.

Robert Janeway must be mentioned when talking of combustion-chambers. This chamber, like many others to come, is based upon the work done by him, and his work is not in the "just happens" class. The folding of the chamber upwards was a convenience. After having determined what shape the chamber must take, it was found necessary to either fold it up or let it overhang the block, and it could not overhang the block. After the general shape and a possible place for the spark-plug was determined, we were afraid the plug would be found to be in an exhaust pocket that would defeat our purpose; but it turned out that the effect of the shape on the rate of combustion was not lost.

As for steam-cooling, I still believe in it. I read a paper[6] in 1926 showing that an engine can be operated satisfactorily and without harm at the temperature of boiling water; but now, as then, no satisfactory condenser is available. Until a condenser is produced that will not let steam escape after the car is stopped, there will be no steam-cooling. The water continues to boil after the car is stopped, because the engine is still hot and there is nothing to cool it. Some day a condenser will be developed that will do that; then we shall throw away our thermostats and many other fittings.

AUSTIN M. WOLF[7]:—I cannot help but echo what has been said about the cooperation of the various departments. This engine was not the child of one man's brain. The contribution of the foundry ranks in importance with that of the engineering department. Also, the paper demonstrates that, in designing any unit, we should not design merely according to our own personal engineering ideals but according to the economics of a general design and to fit the pocket-book and wishes of the buying public.

Many manufacturers have found that it is almost as cheap to build sixes as fours, provided they have suitable tool equipment and methods. Reduction of recip-

[4] M.S.A.E.—Vice-president, Bendix Corp., New York City.

[5] M.S.A.E.—Erickson Co., New York City.

[6] See THE JOURNAL, March, 1926, p. 255.

[7] M.S.A.E.—Automotive consulting engineer, Newark, N. J.

rocating masses is a virtue of the six, as well as elimination of the annoying secondary forces of the four.

Many engines are too high strung and do not give, in the user's hands, the results anticipated in their design. The large-bore engine does not assume too much that it cannot live up to. While much of what Mr. Taub has presented pertains to low-priced cars, probably more of it can be applied to high-priced cars. Crowding of valve design is particularly noticeable in the present straight eights.

The Study of Splash Lubrication

Many of us have our eyes open to the old-time splash lubrication and will reconsider it, at least for certain uses. All the abrasive matter in the oil is not forced through bearings in this design, because of the particularly well-designed settling-wells above the main bearings.

I should like further information about the dipper on the end of the connecting-rod and Mr. Taub's stroboscope study of it, because that dipper certainly needs special study for speeds of 3000 r.p.m.

Also, what is the pressure setting of the relief valve controlling the overflow to the rocker arm shaft; and is there any possibility of starving that shaft after the main bearings have worn enough to allow a free outlet for the oil?

I should like to know the setting of the semi-automatic spark-advance.

How were the figures in Fig. 15 for the curve of power required to propel the car obtained?

MR. TAUB:—We spent about three years developing that dipper, and I am rather proud of it because I did much of that work. Its form is very interesting, as you will see if you examine one of them in a Chevrolet service station.

We have a crank and connecting-rod cut open and a stroboscope set up so that we can look into the end of them and watch the action of the oil. We find that most of the oil enters on the down stroke, at about 30 deg. from the upper dead-center, at which point there is a column of oil about 3/8 in. high. Just after passing the lower dead-center, there is a column of oil about 1/4 in. high. The chief problems are the width of the dipper, the depth of the dip, and the means for maintaining the oil level in the trough. It is quite possible for the dipper to strike the oil in such a way that the oil is displaced enough so the dipper does not strike it at all on the next revolution. If the dipper is too wide, the engine may be over-oiled.

Bearing fits have no influence on the lubrication of the overhead valve mechanism. The relief valve is used only to give an indication of circulation at the pressure-gage on the instrument-board. The oil begins to flow to the valve-gear at about 20 m.p.h., and the engine ought to run all day without further oiling of the valve-gear after it has been run enough at moderate speed to fill up the system.

The spark-advance required for maximum power at 1000 r.p.m. in some of the combustion-chambers on which we have worked was only 10 or 12 deg.; but 19 to 21 deg. is required for this engine, according to con-

ditions. We have found also that the point of maximum pressure comes later on the indicator cards of this engine than it does with other forms of combustion-chamber. This softens the action of the engine.

CHAIRMAN GEORGE A. ROUND[8]:—We also have been doing some stroboscopic work on splash lubricating systems. Recently we found that one of the reasons that a splash-lubricated engine over-oils is that the dipper throws a large spray of oil to either side, like the waves from the bow of a boat. Some of this oil stays in the air long enough so the next crank strikes it and throws it up into the cylinder-bore. If the form of the dipper is not right, the oil distribution is not good.

I am much in favor of the splash system of lubrication, because it makes one less source of trouble for oil engineers; also I am in favor of the low-speed engine, not only to drive, but because it makes easier the lubrication problem. When we multiply main and connecting-rod bearings with changing clearances, subject to high oil-pressure, by the changes in piston-ring action that occur at high speeds, the possibilities for trouble go up very rapidly. Most of the lubrication trouble comes at high speeds, when the piston-rings begin to misbehave, the aluminum pistons are distorted and the temperature becomes excessive.

I hope a thermostat will be used again in this car to help the engine to get warm in cold weather. Nothing else reduces winter troubles so much as a thermostat and crankcase ventilation.

Piston-Pin Problems

JOHN G. BACH[9]:—There seems to have been a change in the piston-pin bearings; will you explain that?

MR. TAUB:—The upper ends of the connecting-rods used in the first engines of this model were bushed, to avoid taking the piston-pin lubrication from the cylinder-walls. It was found necessary to fit the piston-pin in this bearing with 0.0004-in. clearance to make it quiet. Expansion at the operating temperature, amounting to about 0.0006-in., resulted in seizing that would rock the piston. If the clearance was made greater, the fit would soon become loose enough to cause a rattle.

Troubles like this are the reason for the drilled connecting-rods that have been adopted for several cars recently. We returned to the practice of clamping the piston-pin in the connecting-rod, because lubrication through a drilled connecting-rod could not be provided in an engine like ours.

QUESTION:—Can you explain more fully the reason for the failure of the intermediate main bearings of a six-cylinder engine with a four-bearing crankshaft and the better conditions with a three-bearing crankshaft?

MR. TAUB:—Computations show that the loads on the intermediate bearings of an engine with 3 5/16-in. bore, similar to our own but with four main bearings, are 70 per cent greater than on the intermediate bearing of a three-bearing shaft. Besides, it is common knowledge that manufacturers of four-bearing engines have, one after the other, adopted counterweights to reduce the bearing load. The counterweights bring the torque period down into the driving range, and then harmonizers are required. Returning to basic engineering, there seems to be no reason for making a four-bearing shaft, because it gives such poor result in utility per dollar.
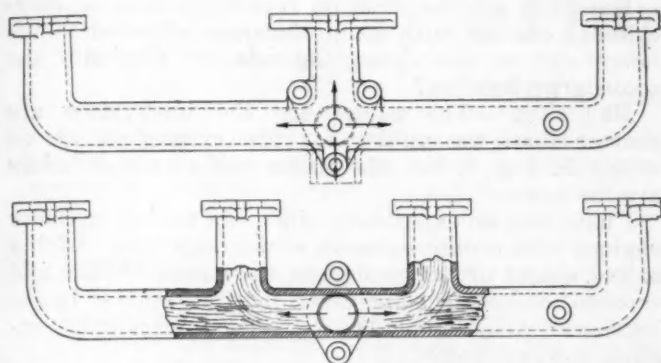
Fig. 16—Comparison of Mixture Flow in Three-Port and Four-Port Inlet-Manifolds

GENE TRIULZI[10]:— Can you give us any data on the life of the main bearings?

MR. TAUB:—I know of three cars that were run at the General Motors proving-ground to check the take-up required for the engine bearings, and the average distance before the removal of one 0.0025-in. shim from the connecting-rod and main bearings was required was 24,000 miles. This was running on a proving-ground circuit of 10 miles, in which 1 mile is equal to 2 miles of ordinary usage. The car is driven 8 of the 10 miles on a track with the throttle wide open, and the remaining 2 miles is devoted to going up and down hill in first and second gear. This also demonstrates the effectiveness of the lubricating system, because, no matter how big the bearings are, such life could not be obtained without lubrication.

QUESTION:—What types of piston and piston-ring are used in this engine, and how many rings?

MR. TAUB:—The piston is oval, made of cast iron, and solid rather than of the skeleton type. I believe the industry has seen the last of skeleton pistons. There are two plain rings, 5/32-in. wide and one oil ring of the same width. The pressure of each ring is 8 to 10 lb., the gap is 0.005 to 0.008 in. and the clearance at the sides of the grooves is 0.0025 in.

An Advocate of High-Speed Engines

T. J. LÍTLE, JR.[11]:—It is unfortunate that the foundry and machine-shop require heavier sections of metal than are dictated by good engineering design. A light, curved wall is better for a crankcase than a heavy wall with straight sides; I agree with Mr. Kettering's phrase "the more cast iron, the less brains." Apparently the real reason for the use of the three-bearing crankshaft in the Chevrolet is to minimize cost; but the load on the center main bearing seems disproportionate. The defense of splash lubrication is clever but not convincing.

Mr. Taub's proof of the superiority of a six-cylinder engine over a four is complete. An identical argument establishes the superiority of an eight over a six. Modern standards of design demand higher compression and higher output than this engine gives; also a higher ratio of power to car weight.

The efficiency of L-head engines is now so high that I wonder if anything but tradition justifies the use of an overhead valve engine in a low-priced automobile. Why are not aluminum pistons used?

MR. TAUB:—Aluminum pistons are necessary to secure higher performance by engines of higher compression, or for higher speed than that for which the Chevrolet engine was designed, but why should the additional cost of aluminum pistons be assumed for a car that is designed for the maximum result per dollar?

Mr. Lítle seems to have overlooked my statement that "If accuracy cannot be maintained, the *construction must be changed* or metal added." This would include curved walls.

The load on the center bearing is always the controlling load of a three-bearing crankshaft; so, when the load is safe for this bearing, the front and rear bearings usually have lower unit loads.

Following tradition is not a bad idea, particularly if the tradition has virtue.

QUESTION:—Why is the camshaft driven by gears?

MR. TAUB:—A few years ago it was thought that the simple two-gear drive was troublesome in a six-cylinder engine, because of vibration periods which would cause noise after the gears had developed a back-lash of about 0.007 in. Since then improved material has been developed. We equipped three engines with Celeron gears and ran them to test the gear wear. A careful inspection was to be made every 24 hr., and I expected to make a curve showing the wear after 75 hr., throw the gears away and put a chain drive in place of them. After 300 hr. at 2600 r.p.m., we could find no back-lash in the gears. There seems to be just enough swelling in this material to counteract the slight wear. We are not justified in using a chain drive, on the basis of result per dollar.

QUESTION:—Was it found necessary to change the spark-plug gap from a standard setting to 0.025 in. in this combustion-chamber. and was there any experimenting with the spark-plug gap to determine whether a difference of a few thousandths of an inch makes any appreciable difference in the ignition?

MR. TAUB:—If this engine was so delicate that a difference of a few thousandths of an inch in the spark-plug gap would affect it, we would not produce it.

QUESTION:—Are the piston-pins or any other parts of the engine chromium-plated?

MR. TAUB:—The piston-pins are chromium-plated.

Horsepower Tax and Exporting

K. J. HOWELL[12]:—Mr. Taub has given definite facts concerning the actual advantages of the "square" engine which tend to substantiate, in this particular case, the claims that this type is superior in many ways to the type having a small bore and a long stroke. A large-bore engine is in an unfavorable position, however, both in ratio of rated to actual horsepower output and for taxation in many States in this Country and other countries, because of the common formula for horsepower in which the square of the bore times the number of cylinders is divided by 2.5. The annual tax in England is approximately $4.85 per horsepower according to this formula, which is based on the bore and does not consider the stroke. This formula not only fails to represent the actual output of any engine, but it also handicaps the large-bore engine.

One manufacturer in the past built a 3¾ x 6¾-in. engine that was taxed in this Country and generally abroad as 22 hp. and actually developed over 80 hp.

[10] Riffert Chevrolet, Inc., Long Island City, N. Y.

[11] M.S.A.E.—Chief engineer, Marmon Motor Car Co., Indianapolis.

[12] Jun.S.A.E.—General supply department, General Motors Export Co., New York City.

This was a decided advantage as to taxation and a powerful sales argument if skillfully handled by the salesman.

The large-bore engine has sufficient advantages to warrant the revision of the inaccurate and obsolete horsepower-formula, not only to remove the present handicap that this formula places on the large-bore engine but also to give us a formula more truly and generally representative of the actual horsepower of modern engines.

It seems logical to develop a new horsepower formula more truly representative of the actual horsepower. Many States in this Country have been replacing the horsepower formula with more accurate data on which to base registration fees, and several overseas territories have been developing new horsepower formulas. Nevertheless, there still appears to be a demand for a formula truly representing the actual horsepower and not penalizing one type of engine and favoring another.

MR. TAUB:—The effect of large bores on the export problem is well recognized. That is the only real protection that Europe has against American cars. So long as the Europeans penalize large bores, it will be hard to export to them American cars as used here.

A. C. WOODBURY[13]:—Are the valve-guides in all six cylinders the same?

[13] M.S.A.E.—Editorial department, S.A.E. JOURNAL, New York City

Have you any information regarding tests of four-cylinder engines with counterbalances attached to the lower end of the connecting-rods, to eliminate the secondary vibration?

MR. TAUB:—The guides for the inlet-valves are shorter than the guides for the exhaust-valves, as shown in Fig. 3, but the guides for all six cylinders are the same.

I have had no experience with tests on four-cylinder engines with counterbalanced connecting-rods. Adding to the weight of the connecting-rod causes trouble and expense, because the increased inertia requires larger bearings. Why should we consider four-cylinder engines now, anyway?

MR. BACH:—Why is a three-port inlet-manifold used instead of a four-port manifold?

MR. TAUB:—The upper view of Fig. 16 shows the general form of the Chevrolet manifold. If a fourth branch is added, as shown by the broken lines, it is evident that any liquid fuel would follow the air-stream as readily into one of the branches as into any other. Omitting the fourth branch makes no difference; the three-port manifold gives equal distribution. With the four-port manifold, shown in the lower part of Fig. 16, unvaporized fuel tends to overrun the two central ports and there is no way of equalizing the mixture unless the engine operates on dry gas; and I know of no engine that does operate on dry gas.

Some Recent Welding Accomplishments

RECENT progress in welding has not been confined to any one method. Several companies have developed automatic machines for arc-welding of tubing, pipes, barrels, tanks, pressure vessels, and special machine parts. It is possible successfully to weld vessels to be used at high temperatures in the presence of oxidizing flames or under conditions that subject them to corrosion.

Boxes for annealing tin plate, containers for solutions for heat-treating metal parts, and lead-refining kettles with capacities up to 250 tons of molten lead are examples of such products. Retorts have been welded of 1½-in. plate up to 24-in. diameter and 36 ft. long for service at 1740 deg. fahr., and petroleum cracking-stills 8 ft. in diameter and 50 ft. long, tested to a pressure of 1700 lb. per sq. in. and designed to operate at a temperature of 1650 deg. fahr. The metal in the weld, under these severe conditions, oxidizes less than that in the vessel itself. Thick-walled welded vessels have even been tested up to pressures of 3600 lb. per sq. in. Several steel buildings and steel bridges have recently been constructed, electrically welded throughout. The German Navy recently launched an arc-welded alloy-steel cruiser.

Steam boilers for high and low pressures will doubtless presently be fabricated by arc-welding, and pressures beyond the limits now used will perhaps be allowed in steam-boiler practice as soon as it is realized that vessels fabricated by fusion-welding have already proved capable of withstanding much severer tests than those now imposed on riveted boilers.

The General Electric Co. a few years ago developed a welding process that employs hydrogen gas in connection with an electric arc. Much higher temperatures are at-

tained than by an ordinary hydrogen flame. In another arc-welding process the welding is carried out in an atmosphere of a reducing gas, by means of an automatic machine that practically eliminates the human element and produces a weld which is perfectly fused, free from impurities and of great strength. Twelve years ago the inventor of this process made aerial-bomb shells by electric welding. These were followed by automobile rear-axle housings. Then came oil-field pipe couplings, oil-cracking stills and other high-pressure vessels for the process industries. Recently this company has been producing welded gas and oil-line pipe by electric welding at the rate of 26 miles per day, in diameters ranging up to 26 in. Altogether, more than 2500 miles of such electrically welded pipes have been built and put into operation. Large penstocks for hydro-electric plants, arc-welded from plates 2 to 3 in. thick, have been made by the same company.

By the best of the newer methods, inclusion of oxides and other contamination in the welded joints has been practically eliminated. Strength tests of specimens cut from the walls of such welded vessels, several inches thick, show that the metal at the weld and adjacent to the weld is not weakened but is actually refined and strengthened. It is possible to produce welds having the same yield and ultimate strength as the plates joined.

Similar results have been obtained with sheets up to ⅜ in. in thickness, welded by the oxyacetylene process. Fatigue tests on arc-welded material have shown the endurance of the deposited metal to be at least 10 per cent above that of the neighboring material. It is also possible to weld corrosion-resisting chromium and chromium-nickel steel of any thickness.—*Arthur D. Little Industrial Bulletin.*

Horsepower Correction for Atmospheric Humidity[1]

By Donald B. Brooks[2]

SEVERAL series of tests made on two multi-cylinder engines to determine the effect of humidity on engine performance are described and the results discussed. The basis for these tests was the so-called oxygen-content hypothesis that the presence of any given volume of water vapor in the cylinder, by lessening the oxygen present, reduces the quantity of fuel that can be burned efficiently per cycle and correspondingly decreases the power output. The results obtained closely verified this hypothesis.

AT a meeting early this year the National Advisory Committee for Aeronautics appointed Dr. H. C. Dickinson, of the Bureau of Standards, as chairman of a special subcommittee to consider the question of a humidity correction for engine tests. As a result of this, a test program, contemplated for some time, was undertaken. Several series of tests were made on two multi-cylinder engines.

The reason for presuming *a priori* that humidity would have an effect on engine performance is that water vapor, which does not play a direct part in the combustion processes, does displace the chemically active oxygen in the limited volume of the cylinder, and hence less material can react during each combustion cycle. In other words, since the presence of any given volume of water vapor in the cylinder proportionately lessens the quantity of oxygen present, less fuel can be burned efficiently per cycle and correspondingly less power is obtained. This conjecture is known as the oxygen-content hypothesis.

Tests by A. W. Gardiner[3], using a one-cylinder engine, are substantially in agreement with this hypothesis. The tests hereinafter described likewise closely verify the hypothesis and suggest other effects of humidity in addition to that due to displacement of oxygen.

Test Apparatus and Procedure

Engine A is a six-cylinder three-port overhead-valve automobile engine of 3⅛-in. bore and 5½-in. stroke. The manifold is jacketed but not hot-spotted, permitting close regulation of the manifold-wall temperature. The engine was coupled to a suitable Sprague electric-dynamometer and to a spark accelerometer[4]. In the three series of tests made on this engine, three different fuels were used, being selected so as to give

[1] Publication approved by the Director of the Bureau of Standards, City of Washington.

[2] S.M.S.A.E.—Associate engineer, Bureau of Standards, City of Washington.

[3] See S.A.E. Journal, February, 1929, p. 155.

[4] See S.A.E. Journal, August, 1928, p. 235.

[5] See S.A.E. Journal, Aug., 1929, p. 135.

As double interpolation is necessary in humidity tables for water-vapor pressure, the process is both laborious and conducive to errors, contour charts reducing both troubles only to a certain extent. Nomograms enabling the humidity correction to be obtained from thermometer and barometer readings were employed and are included in the paper. Instructions for using the nomograms are given and the method of their computation is reviewed briefly in an Appendix.

little or no detonation at optimum spark-advance at any test condition.

Engine B is a Class-B truck engine, having a 4¾-in. bore and 6-in. stroke and of four-cylinder two-port L-head design, and is coupled to a suitable Sprague electric-dynamometer. The manifold is hot-spotted but not jacketed. Tests were made on this engine at three compression-ratios. Different fuels selected by the criterion stated above were used with the different compression-ratios, except in the case of test series No. 6, in which the fuel was such as to give severe detonation at optimum spark-advance. Power measurements were made on the dynamometer. Friction measurements were made on Engine A by the spark accelerometer[5], and checked by the dynamometer. In the case of Engine B, only the dynamometer was used.

Humidification was obtained by passing steam and cold air into a mixing chamber and thence over a heater. Measurements of humidity were made, on Engine A, by continuously bypassing a part of the carbureter-air supply over calibrated dry and wet-bulb thermometers graduated to 0.2 deg. fahr. On Engine B, the thermometers were placed directly in the carbureter-air supply-line. This arrangement, while simpler, introduces an error, due to evaporation of water from the wet bulb. This error, however, is comparatively unimportant. All measurements of humidity are expressed as pressure of water vapor in millimeters of mercury.

In all tests, maximum power and optimum spark-advance were found by one of two procedures: (a) by plotting the results taken at from six to eight values of the spark advance for each humidity and air-fuel ratio or (b) by trial.

Table 1 gives test conditions and procedures, the proportions of the fuels used and the range of air-fuel ratios and humidities covered in the test series. When the first procedure was followed, least-squares solutions were used instead of plotting when the data were of such number as to justify this method.

Before proceeding to discuss the data presented in

TABLE 1—TEST CONDITIONS AND PROCEDURES[6]

Test Series	1	2	3	4	5	6	7
Number of Test Runs	44	87	23	21	18	14	16
Engine	A	A	A	B	B	B	B
Results Plotted in Fig.	1	2	3 & 4	5	5	5	5
Compression Ratio	4.40	4.40	4.40	2.09	4.20	4.92	4.92
Speed, r.p.m.	500	500	500	700	500	500	500
Fuel[7]	$2a + 1b$	$1a + 1b$	d	c	$1c + 1b$	$1a + 1b$	b
Air-Fuel Ratio	13.5	12–16	9–17	12	12	12	12
Air-Horn Temperature, deg. cent.	30	30	41	40	40	40	40
Air-Horn Temperature, deg. fahr.	86	86	106	104	104	104	104
Jacket-Water Temperature, deg. cent.	75	75	70	75	55	55	50
Jacket-Water Temperature, deg. fahr.	167	167	158	167	131	131	122
Humidity, mm. of mercury	5.1–31.9	4.5–28.2	13.4–58.2	14.8–51.0	18.8–55.4	20.2–55.1	12.5–52.4
Humidity, in. of mercury	0.20–1.25	0.18–1.11	0.53–2.28	0.58–2.01	0.74–2.18	0.80–2.18	0.49–2.06

[6] In all tests except Series 3 the optimum spark-advance and maximum power were faired from power readings at six to eight spark advances. In Series 3 the optimum spark-advance and maximum power were found by trial.

[7] The fuels used are designated by the following symbols: a—Eastern domestic aviation gasoline; b—benzol; c—United States Motor gasoline; d—commercial aviation gasoline, approximately equal in antiknock value to a blend of equal parts of a and b.

Figs. 1 to 5, two apparently discordant curves need explanation. In Fig. 2, with Orifice No. 43 an increase in power with humidity is shown. This was the orifice giving the leanest mixture with which firing was possible; the increase in power is due to what is in effect an enrichment of the mixture with increasing humidity. This effective enrichment follows from the fact that, while fuel-flow is practically unaltered by humidity, the quantity of oxygen received by the cylinder decreases as humidity increases. The oxygen-fuel ratio therefore decreases with increasing humidity; hence, if the mixture used is lean, an increase in power with humidity may occur, as in this case.

The second anomaly is in the case of the lower curve of Fig. 5, which shows very much less change of power with humidity than does any of the others. In this case, severe detonation at optimum spark-advance presumably is responsible. Since detonation, even at optimum spark-advance, decreases rapidly with increasing humidity, the smaller loss of power due to detonation tends to cancel the greater loss of power due to increasing humidity.

Discussion of Test Results

The tests shown in Figs. 1, 4, and 5 indicate a linear relation between power and humidity, as do the tests made by Gardiner. The loss of power is seen, in Figs. 4 and 5, to equal the humidity approximately, the hu-
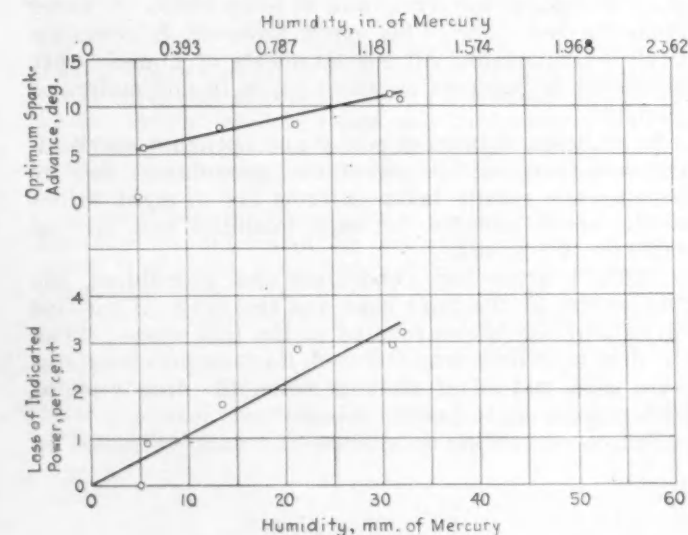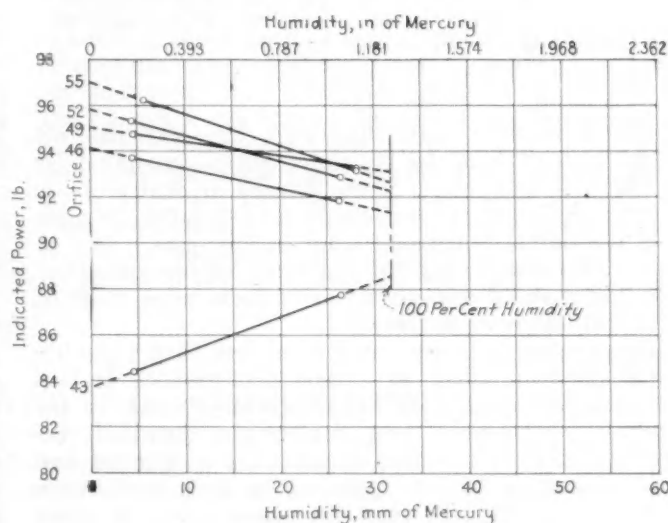
FIG. 2—EFFECT OF HUMIDITY ON POWER

Orifice No.	Loss of Power 0 to 100 Per Cent Humidity, Per Cent
55 (Rich)	4.45
52	3.70
49	2.05
46	2.85
43 (Lean)	5.80 (Gain)
At Best Power, Faired from Mixture-Power Plot	4.41
Theoretical	4.20

FIG. 1—EFFECT OF HUMIDITY ON ENGINE PERFORMANCE

midity being expressed as per cent of the total pressure. From this equality has been evolved the oxygen-content hypothesis, that the power is proportional to the oxygen content by weight of unit volume of atmosphere. From all results obtained in this investigation, the loss of power with humidity is almost identical with that required by the hypothesis, the weighted mean loss being 100.5 per cent of that required by the hypothesis.

However, humidity has some indirect effects on power, as well as the direct effect due to displacement of oxygen. Fig. 6 shows the decided increase in optimum spark-advance with humidity. For Engine A, which operated at a single compression-ratio, the increase of spark advance is 2 deg. per cm. of humidity, irrespective of the fuel used. On the basis of curves presented in National Advisory Committee for Aeronautics Technical Report No. 276, and if the progress of combustion is similar at all humidities, this increase of optimum spark-advance should entail a loss of power 13 per cent as large as that due to the decrease of oxygen. In other words, if humidity affects only oxy-

gen content and optimum spark-advance, the loss of power in this particular case should be 113 per cent of that predicted on the oxygen-content hypothesis.

The average loss of power in the case of tests on Engine *A* is 101 per cent of that predicted by this hypothesis. Since the probable error is less than 3 per cent, other factors obviously tend to compensate for the loss of power due to reduction of oxygen content and increase of optimum spark-advance. Such other factors may include less heat-loss, dissociation and change of specific heats, all due to the lower maximum-temperatures resulting from dilution of the charge by inert water-vapor. The effect of these factors may vary with operating conditions. In the case of Engine *B*, the results suggest less compensation at low compression-ratios.

In Fig. 3, the specific fuel-consumption curves at the two humidities are seen to be displaced horizontally but have practically the same minimum. Moreover, this horizontal displacement is equal, in per cent, to the
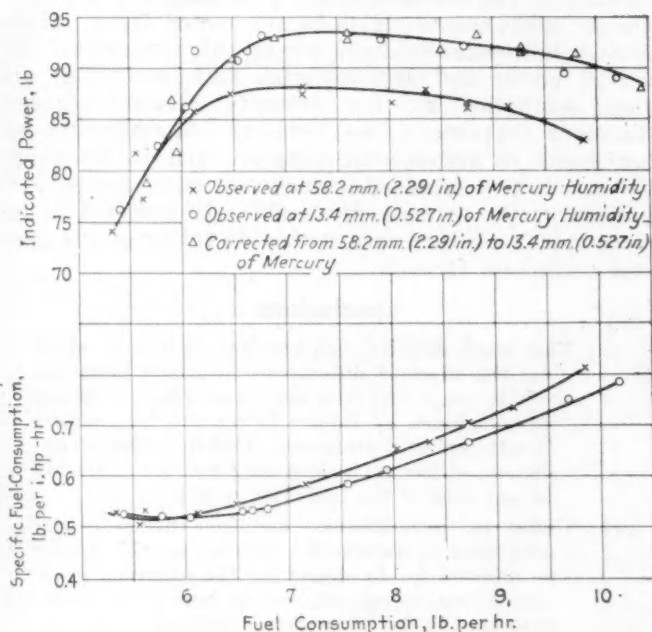
FIG. 3—EFFECT OF HUMIDITY ON POWER AND FUEL CONSUMPTION

percentage difference in oxygen content of unit volume of the atmosphere at the two humidities. This indicates that, in correcting a power versus fuel-consumption curve for humidity, the fuel consumption also must be multiplied by the correction factor, since fuel consumption is here used in place of air-fuel ratio. This correction has been made in Fig. 3, in which the points indicated by triangles represent results obtained at the higher humidity and corrected to the lower humidity. A single curve satisfactorily fits both the corrected data and the observed data obtained at the lower humidity.

Gardiner[a] found a decrease of 7.3 per cent in fuel-flow with increasing humidity over a range of about 49.5 mm. (1.949 in.), and states that a decrease of only 1.4 per cent would be expected if fuel-flow were assumed to vary as the square root of the moist-air density. The average of all results obtained in this work, computed to the same range of humidity, indicates an in-

[a] See S.A.E. JOURNAL, February, 1929, p. 157.
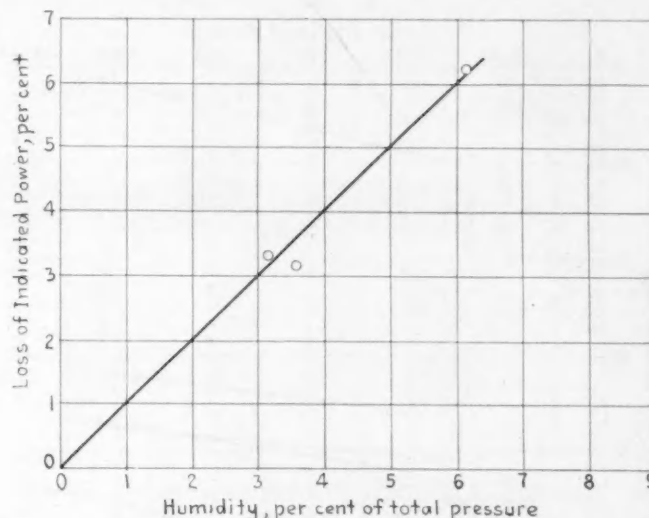
FIG. 4—SUMMARY OF TESTS ON ENGINE *A* SHOWING THE EFFECT OF HUMIDITY ON POWER

The Sloping Line Represents the Total Loss Predicted from the Oxygen-Content Hypothesis. The Weighted Mean of Observed Results Equals 101 Per Cent of the Predicted Power-Loss

crease in fuel-flow of 1.3 per cent. The true flow is therefore probably in accordance with the square root of the moist-air density, the differences between the two sets of observations and theory being due presumably to experimental error.

Interpolation in humidity tables for water-vapor pressure is both laborious and fruitful of errors, since double interpolation is necessary. Contour charts reduce both troubles only to a certain extent. Alignment charts, or nomograms, are believed to furnish the most satisfactory means for obtaining humidity from thermometric observations.

Figs. 7 and 8 are nomograms for obtaining water-vapor pressure, humidity correction to the barometer
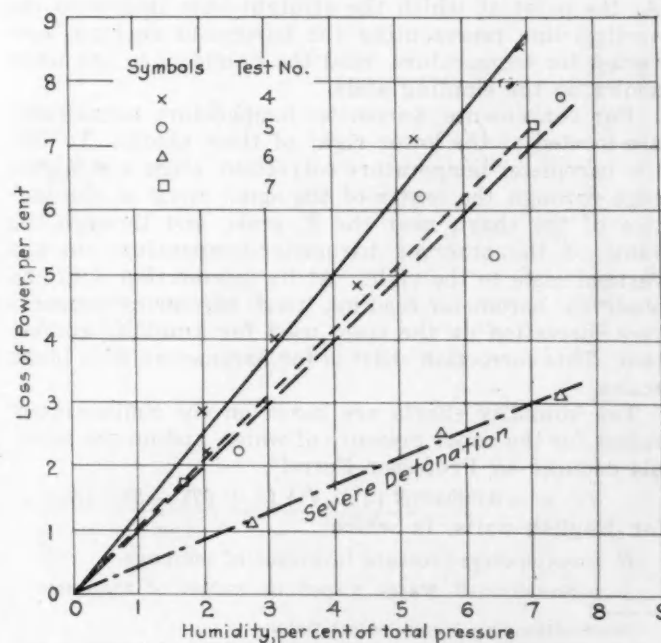
FIG. 5—SUMMARY OF TESTS ON ENGINE *B* SHOWING THE EFFECT OF HUMIDITY ON POWER
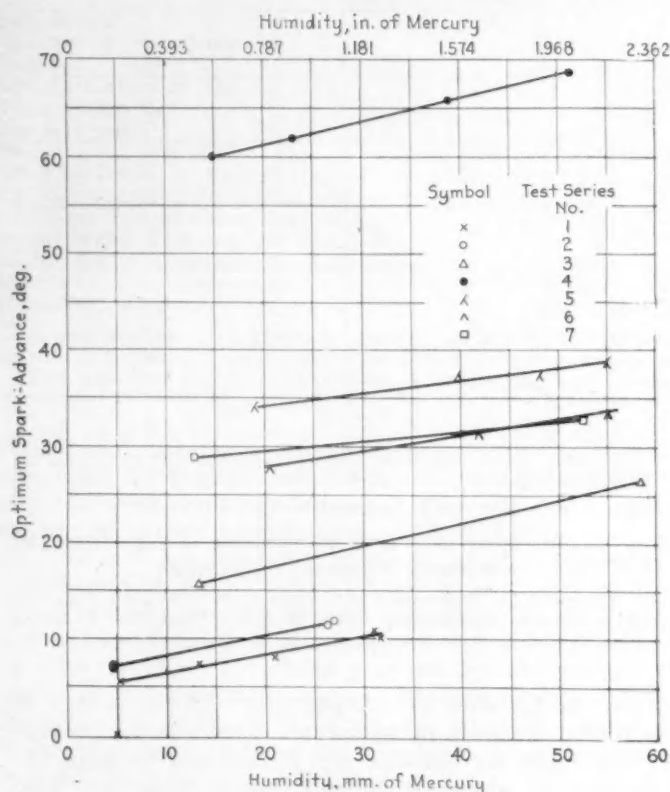
FIG. 6—EFFECT OF HUMIDITY ON OPTIMUM SPARK-ADVANCE

reading, from wet and dry-bulb and barometer readings. Fig. 7 is in units of degrees centigrade and millimeters of mercury pressure, while Fig. 8 is in units of degrees fahrenheit and inches of mercury pressure.

To use these charts, place a straight-edge so that it intersects the T-T_1 scale at the value of the difference between the wet and dry-bulb readings and intersects the T_1 scale at the value of the wet-bulb temperature. At the point at which the straight-edge intersects the vertical line representing the barometer reading, corrected for temperature, read the humidity in the units shown on the slanting scale.

For convenience, barometer-temperature nomograms are located at the lower right of these charts. To find the barometer-temperature correction, align a straight-edge through the center of the small circle at the bottom of the chart, near the T_1 scale, and through the value of the observed barometer-temperature on the vertical scale to the right. At its intersection with the observed barometer-reading, read barometer-temperature correction on the scale used for humidity correction. This correction chart is for barometers with brass scales.

The humidity charts are based on the Smithsonian[9] values for the vapor pressure of water, and on the formula deduced by Professor Ferrel[10],

$$e = e_1 - 0.000367B \ (T - T_1) \ [1 + (T_1 - 32)/1571]$$

for English units, in which

     $B =$ barometric pressure in inches of mercury

     $e =$ pressure of water vapor in inches of mercury

[9] See Smithsonian Meterological Tables.

[10] See Annual Report of the Chief Signal Officer for 1886, p. 233.

[11] A more complete analysis is given by the author in an article entitled Correcting Engine Tests for Humidity which will be published in an early issue of the *Bureau of Standards Journal of Research*.

corresponding to dry and wet-bulb temperatures T and T_1 respectively in degrees fahrenheit

    $e_1 =$ vapor pressure of water at temperature T_1 in degrees fahrenheit

and on the same formula with appropriate constants for metric units and degrees centigrade.

These charts assemble on one sheet the barometer corrections that are significant in automotive work; they are sufficiently accurate for this work and are less laborious, as well as less productive of errors of computation, than psychrometric tables or contour charts. Other barometric corrections, which include free-air altitude, latitude and capillarity, are negligible for automotive work in this Country, since the first two total less than 1 mm. (0.03937 in.), while the third, which is of the opposite sign and generally of much the same magnitude, tends to cancel them.

In correcting engine-performance data to standard conditions, the corrections for both humidity and barometer temperature are to be subtracted from the observed barometer-reading, giving air pressure. Observed power and corresponding fuel-flow values are then multiplied by the pressure correction-factor, Standard Pressure ÷ Air Pressure, thus allowing for variations in atmospheric pressure and in humidity. To correct to a standard temperature is, of course, still necessary; the formula given above is intended to replace merely the pressure correction-factor of the general correction formula.

Conclusions

(1) This work definitely shows that failure to allow for the effect of differences in atmospheric humidity may introduce errors as great as would be occasioned by failure to correct for changes in atmospheric pressure. Under extreme conditions, either correction may amount to nearly 10 per cent of the indicated power.

(2) Under all atmospheric conditions normally encountered in automotive testing, humidity may be allowed for by deducting the observed pressure of water vapor from the barometric pressure used in the power computations.

(3) The proposed correction represents the observed effect of humidity well within the usual precision of measurements, as the indirect effects of humidity apparently cancel one another, at least in the automobile range of compression ratios.

(4) In correcting engine-performance data obtained at different air-fuel ratios, the fuel-flow values must be multiplied by the same coefficient as the power values.

(5) Optimum spark-advance increases linearly with increasing humidity.

(6) Alignment charts presented herewith offer the simplest means of obtaining humidity from psychrometric data.

APPENDIX 1

Method of Computation of Charts[11]

The Ferrel formula for the determination of the water-vapor pressure,

$$e = e_1 - 0.000367B \ [1 + (T_1 - 32)/1571] \ (T - T_1) \quad (1)$$

reduces, for a selected value of B, to

$$e = e_1 - (a + bT_1) \ (T - T_1) \quad (2)$$

where a and b are constants.
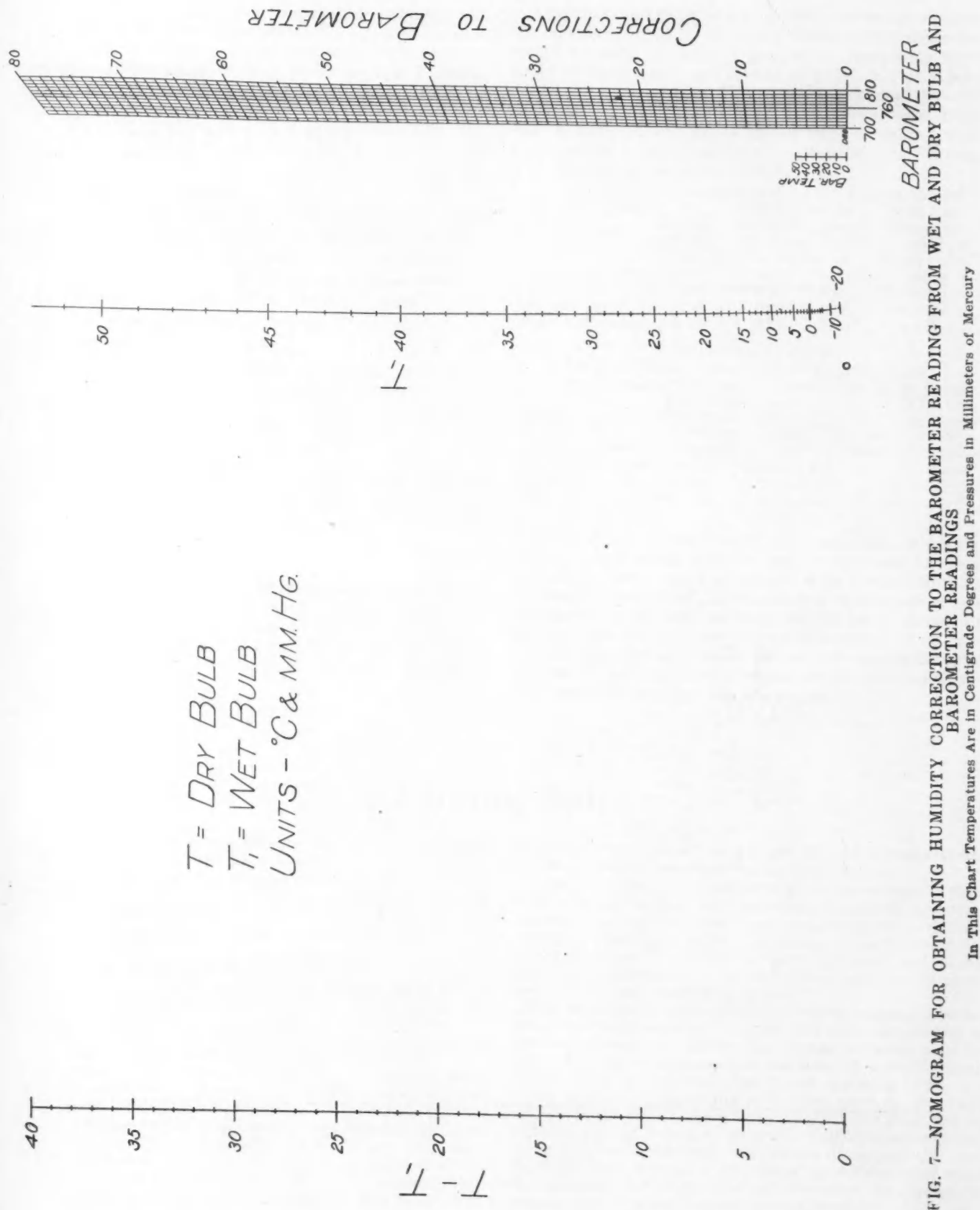
FIG. 7.—NOMOGRAM FOR OBTAINING HUMIDITY CORRECTION TO THE BAROMETER READING FROM WET AND DRY BULB AND BAROMETER READINGS

In This Chart Temperatures Are in Centigrade Degrees and Pressures in Millimeters of Mercury
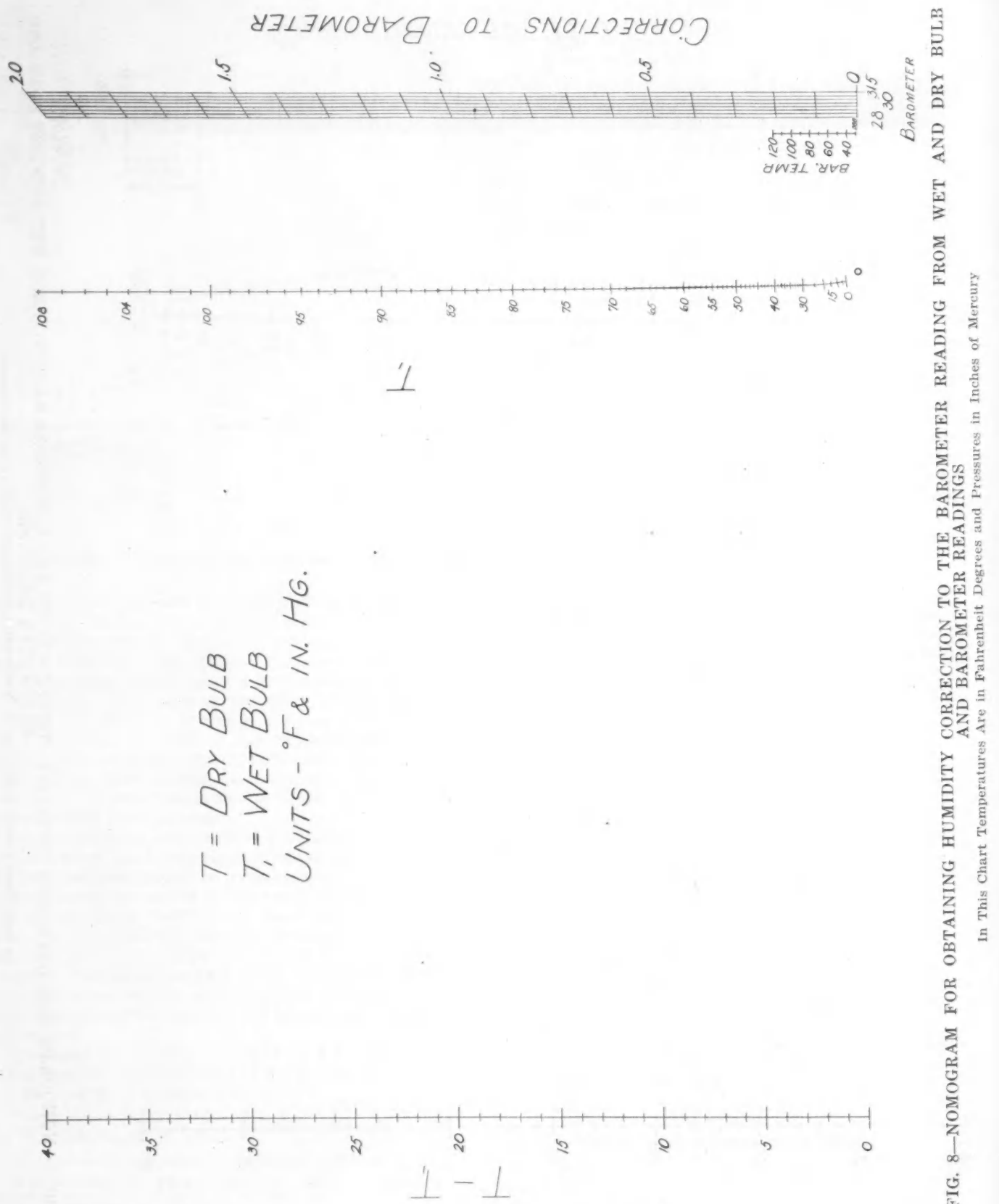
FIG. 8—NOMOGRAM FOR OBTAINING HUMIDITY CORRECTION TO THE BAROMETER READING FROM WET AND DRY BULB
AND BAROMETER READINGS

In This Chart Temperatures Are in Fahrenheit Degrees and Pressures in Inches of Mercury

With this as a basis, charts are constructed as follows: Suitable scales are selected for $T - T_1$ and for e, as in Fig. 7 or 8. Let the length of one unit of $T - T_1$ be m; the vertical length of one unit of e be n; and the horizontal distance between the $T - T_1$ and e scales be p. Then, if x and y are respectively the horizontal and vertical distances of any point on the T_1 scale, measured from the origin of the $T - T_1$ scale, it can be shown from Equation (2) that

$$x = pm/[m + n(a + bT_1)]$$
$$y = mne_1/[m + n(a + bT_1)] \qquad (3)$$

From the specific values of x and y from Equation (3), the T_1 scale is constructed.

In constructing scales for humidity values at other barometric pressures, either of two procedures is used. Calling the new barometric pressure hB and letting

p_1 = value of p with B barometric pressure
p_2 = value of p with hB barometric pressure

then, if h is nearly unity, as in Figs. 7 and 8,

$$p_2 = p_1(1 - [n(1 - h)/2m]) \qquad (4)$$

is a sufficiently close approximation for the value of p_2 for units of degrees centigrade and millimeters of mercury. The analogous equation for p_2 in a chart in units of degrees fahrenheit and inches of mercury is

$$p_2 = p_1(1 - [n(1 - h)/92m]) \qquad (5)$$

If, on the contrary, h is to assume values differing materially from unity, it can be shown that

$$p_2 = mp_1/[m + n_1(1 - h)(a + bT_1)] \qquad (6)$$

and

$$n_2 = (p_2/p_1) n_1 \qquad (7)$$

where n_1 = value of n at B barometric pressure and n_2 = value of n for the new barometric pressure, hB. However, the error introduced by use of the approximate Equations (4) and (5) instead of (6) and (7) is not large enough to be visible on the scale of Figs. 7 and 8.

APPENDIX 2
Precision of Charts as Reproduced

A word as to the precision of these charts for humidity evaluation may be in order. Twenty-four measurements covering the entire range of temperatures were made on each chart, not on the original, but as reproduced in this article. Values of the humidity were estimated by eye, from Fig. 7, to 0.05 mm., and from Fig. 8, to 0.001 in. These values were compared with those given in the Smithsonian Meterological Tables, with results as tabulated below.

	Metric Chart		English Chart	
	As Reproduced, Mm.	With Correction of +0.08 Mm. Applied, Mm.	As Reproduced, In.	With Correction of −0.0014 In. Applied, In.
Average deviation	0.07	0.04	0.0018	0.0016
Mean error	0.09	0.05	0.0026	0.0021
Probable error	0.06	0.035	0.0017	0.0014
Greatest deviation	0.16	0.09	0.007	0.006

DISTRIBUTION OF ERRORS

Metric Chart			English Chart		
	Number of Errors			Number of Errors	
Magnitude, Mm.	As Reproduced	With Correction of +0.08 Mm. Applied	Magnitude, In.	As Reproduced	With Correction of −0.0014 In. Applied
Over 0.10	9	0	Over 0.003	3	4
0.05–0.10	7	8	0.002–0.003	3	2
0.00–0.05	8	16	0.001–0.002	4	7
			0.000–0.001	14	11

From these two summaries, it is seen that, while applying a correction of 0.08 mm. to the metric chart materially improves its agreement with the Smithsonian Tables, yet both charts as reproduced show mean errors smaller than the least quantity to which a barometer can be read without use of a microscope. It is concluded that the charts as reproduced are sufficiently precise for all humidity determinations involving wet and dry-bulb thermometer observations.

The Farming Industry

THE CONDITION of the farming industry in this Country since the war has hardly been normal and can be entirely isolated from any natural instability that is bound to arise in an industry producing several different kinds of crops, each requiring special topographical and climatic conditions. Inasmuch as farming is dependent on natural forces over which there is no human control, there will always be a certain amount of variation in the prosperity of farmers, exclusive of that which is brought about by the normal operation of business fluctuations. Nevertheless, the present condition certainly cannot be attributed in any measure to ordinary maladjustments between supply and demand. Rather, it is the direct result of three primary influences; namely, the aftermath of the war, the general revolution in methods of farming and distribution of agricultural products that has been taking place during the last several years, and the fact that in recent years agricultural production has been increasing about 50 per cent more rapidly than has population. Each of these alone would be sufficient to lend serious complications to the problem, while the combination of the three has resulted in a farm situation that is the grave concern not only of farmers themselves but also of industry and the Government.

After the war, when agricultural prices collapsed, even more severely in most instances than prices of industrial commodities, the farmers found themselves in a difficult position. The high costs of operation brought about by heavy taxation, cultivation of marginal land, and heavy mortgage indebtedness would not permit satisfactory earnings in a market of declining prices.

The farmers' problem is chiefly one of surplus production, which expresses itself in a level of prices prohibitive to satisfactory income. Either the acreage of farms must be reduced or the surplus must be marketed at a profit. Over a long period of time the usual forces operating in all economic pursuits undoubtedly will drive some of the least efficient farmers into other activities, but the fixed nature of farm capital makes it impossible for satisfactory relief to be found in a wholesale elimination of agricultural productivity such as this. Programs of immediate relief must find an outlet for the surplus and encourage the farmers to reduce costs of operation.—*Guaranty Survey*.

Coordinated Air-Rail Passenger Service

By Charles E. McCullough[1]

DURING the last several years the railroads have been faced with constantly increasing new modes of competitive transportation, and the keenest railroad executives saw plainly the futility of attempting to oppose conditions and tendencies over which they could not hope to have control if they continued to fight for supremacy. The firm belief of railroad executives in the potentialities of the airplane as an auxiliary to rail transportation has led to the development of coordinated air-and-rail service.

The first step in this new service was made effective in September, 1928, when air passenger-service on a regular schedule was established between the East and the Northwest, by way of Minneapolis and St. Paul, by the conjunction of the Pennsylvania, the Great Northern, the Northern Pacific, and the Chicago, Milwaukee, St. Paul & Pacific railroads with the Northwest Airways, Inc., a subsidiary of the Transcontinental Air Transport, Inc., which operates passenger air-service between Chicago and the Twin Cities.

This, the first definite undertaking of combined air-and-rail transportation in the United States, was the forerunner of plans for the establishment in 1929 of transcontinental service between New York City and Los Angeles, bringing the Atlantic and the Pacific oceans within 48 hr. of each other through a combination service by the Pennsylvania Railroad and the National Air Transport, with the Santa Fe Railroad participating as a carrier. By the new transcontinental rail-air service, a passenger leaving New York City at 6.05 p.m., Eastern standard time, will be in Los Angeles in the early evening of the second day, making the trip in 2 days instead of the 4½ days required by fast railroad trains, covering in airplanes 62 per cent of the total distance of more than 2800 miles traveled but only 42 per cent of the time spent in actual traveling. This coast-to-coast service will be only a forerunner of a greatly spreading development of similar service connecting every part of the American continent and bringing distant points closer together through the means of efficiently coordinated railroad and airplane facilities.

Air Passenger-Travel in Europe

Europe has progressed further in the carrying of passengers by air than has the United States but is far behind us in the air-mail transport. The development of commercial aviation in Europe is really remarkable. It has become a business only since the war, yet the German line, since 1920, has multiplied its passenger travel by air 32½ times, and the Dutch airline 26½ times, while the English and French lines have also accomplished substantial results. The shipment of goods by air is growing correspondingly and is being relied upon more and more for increased revenues. The detailed information relative to the air-rail program of

the Transcontinental Air Transport, Inc., was received everywhere in Europe with great interest and predictions were made generally that this Country may expect an even more startling growth than has occurred in Europe.

No interchange relations of any kind between airlines and railroads exist in Europe, except between the Luft Hansa and the State Railways in Germany. The Luft Hansa has an arrangement with the German State Railways whereby, in case of the forced landing of an airplane short of destination, the passenger's air ticket is accepted for passage on a railroad train from the station nearest the place of landing to the destination. The French airlines and those of several other European countries are endeavoring to have similar arrangements made effective with the railroads in their countries.

Must Make Public Air-Conscious

The education of the public to the advantages in time-saving, comfort, dependability and safety of passenger air-transport is being given careful attention by all the airline executives in every European country. This is particularly noticeable in Holland and Germany, where commercial aviation is not based on a military background to the same extent as in France and England. The airline executives avail themselves of every opportunity to talk on the subject before public gatherings, and every encouragement is given to parties of adults and school children to visit the airdromes and inspect the facilities. They are placed in charge of a competent employe, who escorts them through the hangars and buildings, takes them into the cabins of airplanes, and explains all features of the operation that are of interest to the listeners. In addition, fenced-off spaces with seats in some places are provided for the people who come to the airdromes to see their friends arrive or depart, or who visit the field merely to watch the arrival and departure of planes.

We should do more than we are doing in this Country to encourage air-mindedness. Everyone interested in the practical future of aviation and in seeing that our own Country shall not be backward in the march of progress of this new form of transportation, must not lose an opportunity to preach the gospel of the safety, convenience and growing improvements of air travel. The railroads are striving to do their share in this important work; the development of combined air-and-rail services is evidence of that fact. The Pennsylvania Railroad is showing its interest and confidence in the future by going a step further and taking a heavy financial interest in air transport. Many other interests are showing their confidence by making money investments. The cause of public air-consciousness or air-mindedness could be still further advanced if more of our leading business men would show their confidence by personally using the services of the established airline companies when time could be saved in their travels from one point to another.

[1] General passenger agent, Pennsylvania Railroad, City of Washington.

Long-Distance Passenger Services

By R. E. Plimpton[1]

E XTENSION of motorcoach services over routes of 100 miles or more in length in all parts of the Country is shown by a map, and figures are given of the number of routes, the miles of highway over which the services are operated, running time, rates of fare charged and like data. Facilities and operating methods differentiating long-distance from suburban services are mentioned and the similarity to railroad practice pointed out.

A characteristic of routes ranging from several hundred to nearly 1500 miles is that service is afforded continuously for 24 hr. per day seven days per week and many passengers ride day and night. Such long runs are broken into stages so that a driver does not work more than 8 to 10 hr. as a rule and vehicles are changed at the end of a run of a certain distance, which may vary from about 200 to nearly 750 miles. Tickets bearing coupons for the successive stages or divisions are issued, garage facilities are provided at division points, and intermediate stations for passenger comfort and meals are provided, often by others than the operating company.

Factors affecting speed are discussed and the pains-taking care with which running schedules are developed is explained.

Types of vehicle used vary with volume of traffic and road conditions. Standardization of equipment is greatly preferred by passengers and should be practicable ordinarily on lines of a single company.

Sleeper motorcoaches are now being tried between Buffalo and Cleveland and a similar service was started in June between Los Angeles and San Francisco.

Some tendency to find additional sources of revenue than passenger traffic is observed, and at least one long-distance line is engaged in furniture moving. Local and suburban passenger service is operated in conjunction with long-distance services by a number of lines, and a tendency exists to absorb independent connecting lines. Union terminals are maintained in various large cities.

In concluding, the author praises the high type of driver now handling the vehicles and the motorcoach engineers and manufacturers for the great reliability of the vehicles under the severe duty imposed by the service.

O NE of the simplest forms of transportation service is a ride in an automobile. This was true at least at the beginning of bus transportation. John Smith could, and did, serve as owner, driver, mechanic, and perhaps accountant. But when his one-man one-vehicle system had taken unto itself scores or hundreds of passenger-carrying units, and the few miles of route confined to a city or its suburbs had been extended to cover hundreds of miles in many States, management became enmeshed in all the complexities

[1] M.S.A.E.—Associate editor, *Bus Transportation*, Chicago.

FIG. 1—NEW UNION TERMINAL FOR LONG-DISTANCE AND SUBURBAN MOTORCOACH LINES AT OKLAHOMA CITY OPPOSITE SANTA FE RAILROAD STATION
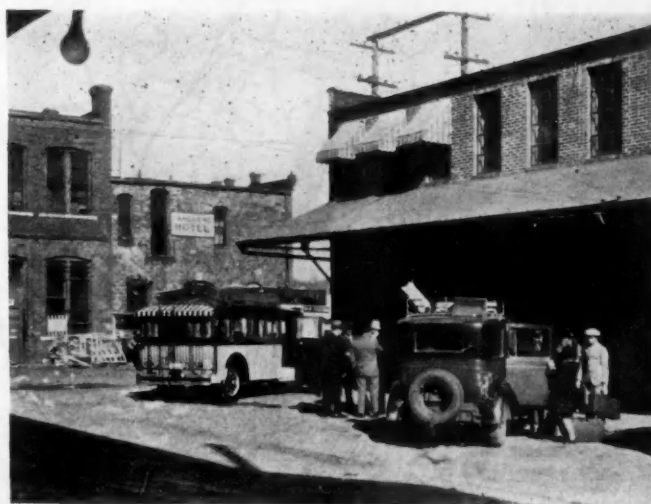
FIG. 2—PRIVATE LOADING SPACE FOR MOTORCOACHES ADJACENT TO WAITING-ROOM AT OKLAHOMA CITY TERMINAL, MADE NECESSARY BY STREET CONGESTION

of large-scale business, with a few distinctive ones thrown in for good measure.

In other lines of industry it usually is admitted that production has outstripped distribution and that the factory is doing a better job than the sales department. The reverse is more nearly true in the case of long-distance motorcoach operation. Of necessity, because of the competitive nature of the service, the selling or traffic department has been more highly developed. All
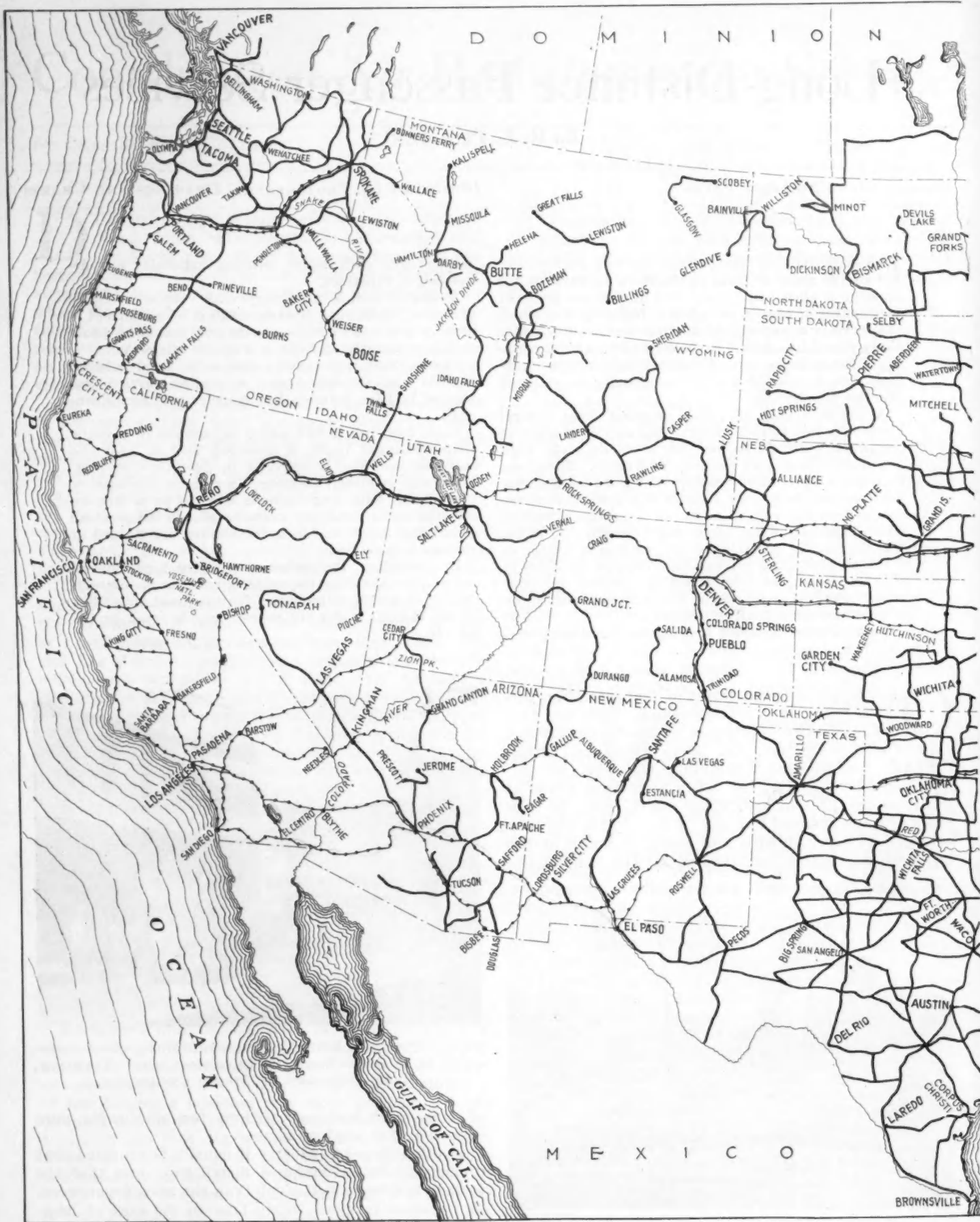
FIG. 3—MAP OF THE LONG-DISTANCE

More Than One-Third of the Intercity Routes Are Operated in Units 100 Miles or More in Length,
Including Pickwick, Yelloway,

MOTORCOACH ROUTES OF THE UNITED STATES

Light Lines with Dots Indicate Routes of the Motor Transport Corp. and Its Affiliated Companies, Oregon Stages and Others

the resources of modern distribution are skilfully employed. The product, or ride, is sold at many and widely scattered points. Advertising is persistent and continuous, on the revenue vehicles and by attractive printed matter, including booklets, timetables and newspaper announcements. Good-looking terminals, of the kind shown in Figs. 1 and 2, also help to bring in the business.

But the operation and maintenance of the motor carriers, corresponding to production in the factory, is a comparatively new problem. Until three or four years ago, routes rarely exceeded 100 miles in length. If a number of them were brought together under a single control, they usually radiated from one or more city centers where the maintenance of the vehicles could be concentrated and the drivers were under daily supervision.

Maintenance and operation must be decentralized on the routes of 500 miles or more, such as are characteristic of the long-distance movement of passengers. So far this decentralizing has been done in a more or less hit or miss manner, but as larger companies enter the field order is succeeding the former chaos. Standardization based upon thorough research is gradually being effected in methods of maintenance and operation; the accident hazard is receiving expert attention; equipment is being improved as fast as is warranted by the condition of highways and the traffic demand; and maintenance facilities are being established at many points on the long routes, providing not only needed mechanical labor but a supply of spare parts and reserve vehicles.

This progress is being made mainly in the type of long-distance services that connect one large center of population with another of comparable size. The highways traversed are surfaced or at least improved to permit all-weather operation. Equipment is of large capacity, single-deck coaches seating 25 to 30 or even more passengers. This type of service corresponds to that of the trunk lines of a steam railroad, as shown on the map in Fig. 3 by the routes of the Motor Transit Corp. and its affiliated companies. It will be noted that the routes are densest in the northeastern States and on the Pacific Coast, both sections in which population density and highway conditions have been unusually favorable.

Another kind of long-distance service is more likely to be intrastate in character and provides in many cases

FIG. 4—A JUNCTION POINT AT CISCO, WEST TEXAS

Routes Branching to the North and South Are Served by Smaller Vehicles than Are Used on the Main Line from Dallas to El Paso
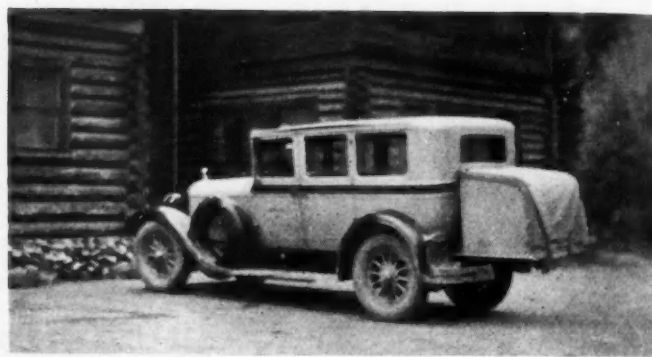
FIG. 5—A REST STOP OF THE BETTER TYPE, AT PATRICK CREEK, CALIF., IN THE MOUNTAINS NEAR THE OREGON STATE LINE

the only public transportation from trading centers to smaller towns and villages. This development is still largely in the pioneer stage; operating companies are small, roads are poor and frequently passable only during part of the year; vehicles may be of the seven-passenger automobile type or at most do not seat more than 18 or 20 persons. Thus, this second type serves the less densely populated parts of the Country, being found mostly in the agricultural States west of the Mississippi River.

The map also indicates, in heavy lines, the location of routes of 100 miles or more, outside of the Motor Transit System. Not all of these are of the light-traffic variety, as in about 20 States companies operating 50 or more vehicles are engaged in long-distance work. These routes connect with those of smaller operators (see Fig. 4), to serve outlying territories.

Seven Hundred Long-Distance Routes

All told, about 700 of these 100-mile routes are being operated now over 100,000 miles of highway, as compared with the 260,000 miles of intercity routes reported in the 1929 statistical issue of *Bus Transportation*. Of these, the group included in the Greyhound-Pickwick-Yelloway-Oregon Stages System has about 60 long lines on 22,000 miles of highway. The members of this group operate about 6000 miles of shorter routes, mostly of the branch-line variety feeding into the main or trunk routes.

The leading State in long-distance routes is Texas, which has about 80 routes on 12,000 miles of highway. California is second, with 30 routes on 6000 miles of highway; followed by Oklahoma and Washington in the West, and Illinois and Ohio in the East. These last four States have from 20 to 30 routes each, aggregating 4000 to 5000 miles.

To assume 100 miles as the distance required before a route attains "long-distance" standing is rather arbitrary, although such routes have many features that differentiate them from the shorter suburban runs. Baggage facilities must be provided on the vehicles; comfort and meal stops are required; and on the best-managed of these routes railroad practice is followed in the selling of tickets, so that the driver collects cash fares only when he takes on passengers at intermediate points.

While all of these features are important, the service lacks one of the most striking characteristics of routes that are several hundred miles long; that is, the fact

that most of the passengers complete their trips only after an all-day and all-night ride. On these long routes, service is afforded continuously 24 hr. per day and seven days per week, and passengers avail themselves of it to a great extent. Trips of 1000 miles or more from Denver to Los Angeles, Chicago to Jacksonville, and Vancouver to Salt Lake City are made by many passengers without any overnight stops.

Operation Stages or Divisions

Long runs of this kind must be broken down into small, and therefore more easily workable, elements. The process of division starts with the ticket, which entitles the passenger to a seat between specified points. Interpoint coupons are detached from the ticket from time to time so that each part of the system can receive financial credit for the work actually done. One vehicle and one driver travel only a limited distance, as a practical operating measure. Any long trip by a passenger means changing both vehicle and driver, but not necessarily at the same time. Another and equally essential aspect of operation by stages, using the word not in its meaning of a vehicle but in the older sense as a regular stopping place on a route of travel, has to do with the accommodation of passengers. Their comfort and convenience demand stops at fairly regular intervals, waiting-rooms with suitable facilities, a time and place to eat. All of these are ordinarily provided apart from the medium of transportation, and thus increase the running time between points.

The "stage" problem is not peculiar to motorcoach transportation; it was solved with the stagecoach of earlier days, when the horses had to be changed every 8 or 10 miles and drivers at somewhat longer intervals. The railroad has division points at which one train crew relieves another and one locomotive is taken off for inspection or light repairs and another that is in good condition is substituted. Air-transport companies find it essential to replace planes and pilots after they have flown a certain number of hours. One such company has set 450 miles as the pilot's stint, while a single airplane makes twice that distance.

On the highway a run of 200 miles is easily accomplished by one driver and one coach. Both can travel back and forth over the route, out one day and back the next, working perhaps 8 or 9 hr. per day. Facili-
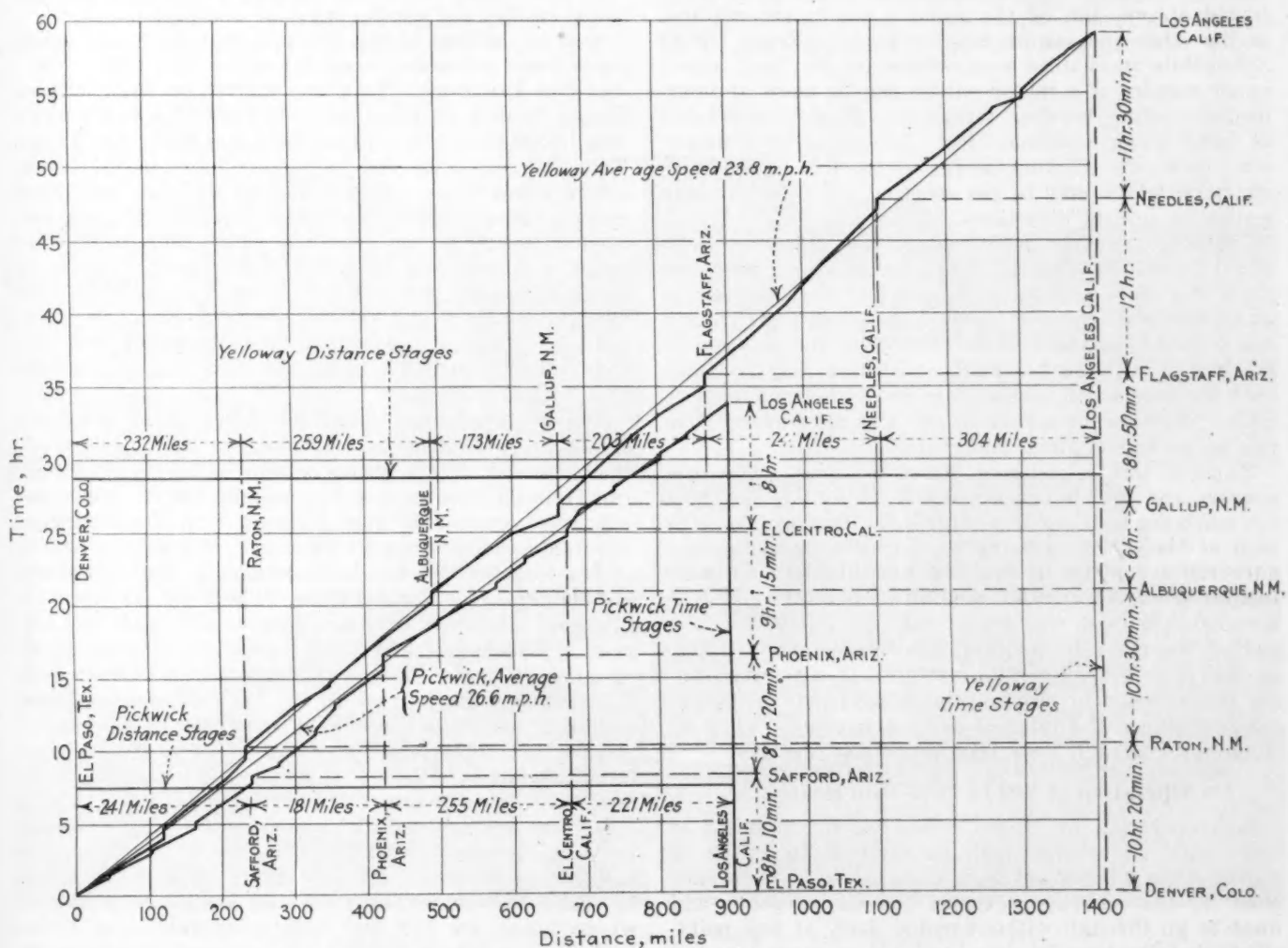
FIG. 6—TIME AND DISTANCE OF "STAGES" OR DIVISIONS COVERED BY DRIVERS ON ROUTES FROM EL PASO AND DENVER TO LOS ANGELES

The Upper Heavy-Line Curve Represents the Schedule of the Yelloway Service from Denver to Los Angeles and the Lower Curve the Pickwick Service from El Paso to Los Angeles. Distances of the Stages Are Given on the Horizontal Heavy Lines and Running Times for the Stages on the Vertical Heavy Lines at 900 and 1400 Miles on the Scale at the Bottom of the Chart. The Light Straight-Line Curves Show Average Speed. Short Vertical Jogs on the Heavy-Line Curves Represent Rest and Meal Stops
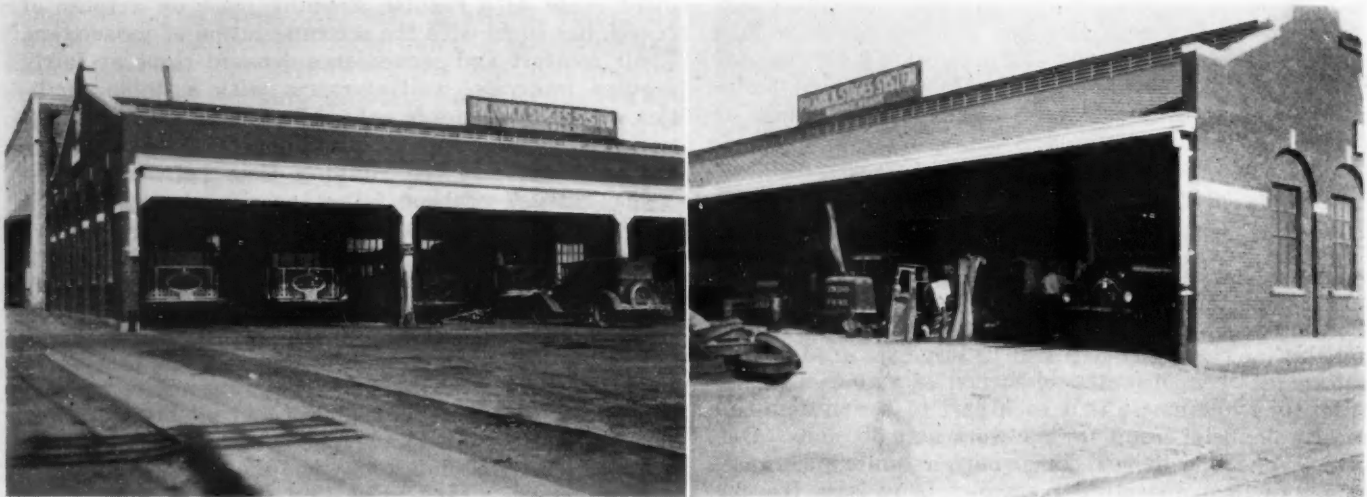
FIG. 7—PICKWICK SERVICE STATION IN ARIZONA, WHERE VEHICLES ARE CLEANED AND INSPECTED AND HEAVY REPAIRS ARE MADE

ties for supervision and maintenance can be concentrated at one end of the route. Any work required at the other end can be done by a local garage. With automobile mechanics everywhere in the land, emergency repairs of a minor nature can be made at intermediate points between terminals. Fuel is purchased at local filling stations. But the operating company aims to handle all work as far as possible at its headquarters, which may be the starting point for its long routes in several directions.

Passenger-facility maintenance may also be delegated. Comfort stops at 2 or 3-hr. intervals often are made at a store or restaurant (see Fig. 5) which serves as a commissioned ticket office of the operating company and is paid to minister to the comfort of the passengers. Or, at the outlying terminal, connection may be made with the coaches of another carrier at his headquarters, which provides better facilities for passengers than can be furnished along the route.

Suppose that a route is 300 miles long. The passengers and vehicle can stand the 12-hr. trip but it is too much for a driver day after day. Overworking the man at the wheel is being discouraged by regulatory authorities and by companies handling the liability insurance carried by all reputable operators. So, on the 300-mile run, the driver may be relieved at the end of 200 miles by another, who makes a round trip on the remaining 100-mile stretch. If schedules cannot be arranged to do this, the drivers may make the entire distance and take off every third day. They do three days' work in two, then must rest one day.

Operation of 500 to 1500-Mile Routes

Real operation by stages comes when 500 miles or more must be covered with no intervening towns of sufficient size to warrant their designation as terminals. Most of the passengers travel the entire route and want to go through without undue delay at any point, although from time to time some riders make trips of only 100 or 200 miles. Also, some patrons want to ride by daylight only, to see the country, and sleep in non-mobile quarters at night. These are permitted to stop over at division points, where the drivers change, which are always fair-sized towns offering hotel accommodations. However, enough passengers ride at night so that the service must be continuous.

One of the first of the 500-mile routes under a single control and ownership was that between Portland, Ore., and San Francisco. This was started by the Pickwick Stages System 10 years ago. In 1925 Pickwick service was introduced between Los Angeles and El Paso, Texas. This line was extended two years later to St. Louis, where connections were made with Chicago and other eastern cities. About four years ago the old Yelloway System began service over the route between Denver and Los Angeles, which is still the longest of the long-distance routes. At first the service was on a daylight basis, passengers and vehicles stopping each night. A year or two ago, before interests connected with the California Transit Co. took over the line, 24-hr. operation was started.

The two routes mentioned are typical of many others of 500 miles or more now operated in various parts of the Country. Fig. 6 shows schedules for the Pickwick run from El Paso to Los Angeles and for the Yelloway run from Denver to Los Angeles. On the Pickwick schedule, coaches leave El Paso at 7:15 a.m. and arrive at Los Angeles 33¾ hr. later, making an average speed of 26.6 m.p.h. for the 898 miles. The Yelloway schedule provides for departure from Denver at 8 p.m. and arrival at Los Angeles, 1412 miles away, in 59¼ hr., or at an average speed for the through trip of 23.8 m.p.h. These speeds are figured on the basis of elapsed time, including all stops for change of drivers, of vehicles and for passenger comfort. Comfort stops are made at 50 or 75-mile intervals, and are for periods of 5 to 10 min., with 20 or 30 min. allowed for meals.

Drivers are relieved at the end of the stages, which vary in distance from 173 to 304 miles (see Fig. 6) and in time worked from 6 to 12 hr. It is not possible to make the stages uniform, especially in territory where towns are few and widely separated. A Pickwick station where drivers are relieved is shown in Fig. 7. Passengers change vehicles once on each route, at Phoenix, Ariz., where several Pickwick routes center, and at Gallup, N. M., on the Yelloway Lines. One Pickwick vehicle thus makes 422 miles from El Paso to Phoenix, and the other 476 miles, to Los Angeles.

The Yelloway tour of duty is about 50 per cent longer, as the first unit covers the 664-mile stretch from Denver to Gallup, and the second unit the remaining 748 miles to Los Angeles.

Garage facilities are provided at all the places mentioned. At Phoenix, as brought out in Fig. 7, Pickwick has heavy-repair facilities. Both companies hold over a vehicle at the end of its run long enough for cleaning and necessary inspection and repairs, then return it over the same section of the route. By working vehicles in this way, each is kept with the same group of operators, responsibility for maintenance is limited to two garage forces, and more of an opportunity is afforded to adapt vehicles to the type of highways traversed. While it is desirable to standardize the equipment for reasons of operating efficiency and to provide through passengers with accommodations of the same quality on each portion of the route, road conditions may sometimes demand the use on one part of the route of a standard-gage vehicle of smaller capacity than can be used elsewhere, or special accessories such as fog lights may be required for only a part of the route. The type of vehicle used in eastern Oklahoma is shown in Fig. 10.

Average speeds on the two routes thus far discussed are much higher than can be maintained on the longer routes east of the Mississipi River, particularly on those in the northern States. In both parts of the Country maximum speeds are limited by laws that are rigidly enforced for public-service vehicles, but in the thickly settled East a great deal of time is lost in passing through cities and towns, and this more than compensates for the better road conditions that prevail there. The longest run in the East, that of the Great Lakes Stages from Cleveland to New York City, passes through Erie, Buffalo, Scranton, Newark and many smaller cities, and the drivers do well to average 25.3 m.p.h. for the 612-mile trip. Schedule speeds for a number of other typical routes are presented in Table 1.

Whether these schedule speeds can be increased to any great extent is open to question. Passengers demand the highest speed consistent with reasonable riding comfort, as most of them desire to reach their destinations promptly and object to schedules that allow for frequent and long stops. Roads are constantly being improved, thus shortening the running distance as well as making higher speeds safe over formerly unimproved portions. It is estimated that the time between New York City and Los Angeles can be cut down 24 hr. after various road improvements are completed. One of these is the elimination of the famous La Bajada hill, Fig. 9, by the construction of a new

SOME SCENES ON LONG-DISTANCE ROUTES WEST OF THE MISSISSIPPI RIVER

Fig. 8—A Tire Change in the Desert East of Toppock, Ariz., Where the Women Passengers Retired After the Driver Mentioned Rattlesnakes

Fig. 9—La Bajada Hill Between Albuquerque and Santa Fe, N. M., Where the Road Rises 900 Ft. in a Little More than a Mile. In a Distance of 35 Miles 175 Gear Changes Are Necessary

Fig. 10—Light Equipment Is Used on the Rainbow Bus Line Between Fort Smith, Ark., and Muskogee, Okla.

Fig. 11—Union Terminal in St. Louis, from Which Service Is Given by the Greyhound, Pickwick and Yelloway Systems and Passengers Interchange with Connecting Lines

TABLE 1—OPERATING DATA FROM 50 TYPICAL LONG-DISTANCE ROUTES

State and Route	Distance, Miles	Running Time, Hr.	Average Speed, M.P.H.	Fares One-Way	Cents per Mile	Cents per Hr.
New England						
Connecticut (1)a						
New Haven–New York City	77	4	19.3	$2.25	2.92	56.3
Massachusetts (2)						
Boston–New York City	237	11	21.5	4.50	2.11	40.8
Maine (3)						
Portland–Boston	123	4½	27.3	2.50	2.03	55.6
New Hampshire (4)						
Bethlehem–Boston	183	9	20.3	7.50	4.10	83.3
Northeast						
Illinois (5)						
Chicago–Peoria	143	5¼	26.7	3.00	2.14	57.3
Indiana (6)						
Indianapolis–Evansville	204	7½	27.2	4.95	2.43	66.0
Maryland (7)						
Philadelphia–Washington	147	6¼	23.5	3.75	2.55	60.0
Michigan (8)						
Muskegon–Chicago	197	8¼	23.9	5.00	2.54	60.7
New Jersey (9)						
Philadelphia–New York City	98	4¼	21.8	2.00	2.04	44.4
New York (10)						
New York City–Albany	156	7	22.3	4.00	2.56	57.2
Ohio (11)						
Cleveland–Columbus	166	6¾	24.6	3.75	2.26	55.6
Pennsylvania (12)						
Wilkesbarre–New York City	141	6½	21.7	4.50	3.19	69.2
Wisconsin (13)						
Madison–Neenah	106	4½	23.6	4.05	3.82	90.1
Interstate (14)						
New York City–Chicago	879	37½	23.4	20.50	2.33	54.6
Southeast						
Alabama (15)						
Birmingham–Decatur	92	4	23.0	2.25	2.45	56.3
Arkansas (16)						
Little Rock–Fort Smith	172	7¼	23.6	5.95	3.46	81.7
Florida (17)						
Jacksonville–Pensacola	350	12¼	28.6	11.50	3.29	94.2
Georgia (18)						
Atlanta–Macon	94	4	23.5	2.50	2.66	62.5
Kentucky (19)						
Lexington–Cincinnati	104	4	26.0	2.50	2.45	63.7
Louisiana (20)						
Baton Rouge–Alexandria	120	4½	26.7	4.65	3.87	103.3
Mississippi (21)						
Natchez–Baton Rouge, La.	100	4⅓	23.1	4.00	4.00	92.4
North Carolina (22)						
Raleigh–Charlotte	165	5	33.0	5.50	3.33	110.0
South Carolina (23)						
Columbia–Charleston	132	4¼	31.1	5.00	3.79	117.8
Tennessee (24)						
Memphis–Paducah, Ky.	175	7½	23.3	4.50	2.57	59.8
Virginia (25)						
Winchester–Roanoke	187	7	26.9	7.00	3.75	101.0
West Virginia (26)						
Charleston–Bluefield	130	6¼	20.8	7.85	6.04	125.7
Interstate (27)						
St. Louis–New Orleans	775	32½	23.8	16.35	2.11	50.3
Northwest						
Idaho (28)						
Twin Falls–Wells, Nev.	130	4½	28.9	5.00	3.85	111.3
Iowa (29)						
Des Moines–Waterloo	136	5¼	25.5	4.00	2.84	75.0
Minnesota (30)						
Mankato–Winona	143	5	28.6	4.30	3.01	86.0
Missouri (31)						
St. Louis–Cape Girardeau	140	5	28.0	2.50	1.79	50.1
Montana (32)						
Billings–Great Falls	263	9	29.2	9.50	3.61	105.6
Nebraska (33)						
Lincoln–Grand Island	94	3 5/6	24.5	3.00	3.19	78.2
North Dakota (34)						
Devils Lake–Jamestown	101	4	25.3	5.25	5.20	131.5
South Dakota (35)						
Pierre–Rapid City	145	5½	26.3	6.00	4.13	109.0
Wyoming (36)						
Cheyenne–Casper	209	7½	27.9	6.25	2.99	83.3
Interstate (37)						
Minneapolis–Kansas City, Mo.	532	18½	28.7	11.65	2.19	62.8
Southwest						
Arizona (38)						
Phoenix–Prescott	113	4	28.3	5.00	4.43	125.3
Colorado (39)						
Grand Junction–Durango	185	9¼	19.6	12.75	6.89	135.0
Kansas (40)						
Wichita–Independence	133	6¼	21.0	4.25	3.19	67.1
Nevada (41)						
Ely–Tonopah	175	7½	23.3	12.50	7.15	166.5
New Mexico (42)						
Las Cruces–Albuquerque	258	7¾	33.3	7.50	2.91	96.8
Oklahoma (43)						
Muskogee–Miami	106	4	26.5	3.40	3.20	84.8
Texas (44)						
Pecos–Big Spring	134	4½	29.8	5.25	3.92	116.8
Utah (45)						
Salt Lake City–Fillmore	151	6	25.2	5.05	3.34	84.2
Interstate (46)						
Houston–Los Angeles	1,863	64	29.1	41.00	2.20	64.0
Pacific						
California (47)						
Los Angeles–San Francisco	460	14½	31.7	11.85	2.58	81.7
Oregon (48)						
Portland–Astoria	105	4⅔	22.3	3.40	3.24	72.9
Washington (49)						
Seattle–Vancouver	157	6	26.2	4.50	2.90	76.0
Interstate (50)						
San Francisco–Vancouver	1,081	43½	24.9	19.50	1.81	44.9

a Numbers in ( ) refer to routes shown in Fig. 12.

valley road. But less important improvements are likely to be offset, with a normal growth of passenger traffic, by the increased time required for station stops.

The greatest opportunity for higher average speed seems to rest with the vehicle itself, through increase of engine power, better acceleration, and gear ratios better suited to the gradients of the routes followed. This development is mostly the manufacturers' responsibility, but the operating company must do its part and not permit the performance to fall below a definite value. A suggestion made in a paper[2] given before the Milwaukee Section of the Society on May 8 might well be taken to heart by motorcoach operators; namely, that engines be rated at a speed the maker is willing to guarantee for continuous duty at 90 per cent of the actual power delivered on test when operating at that speed. Experience has demonstrated, according to the author of that paper, that carefully designed engines can be expected to deliver throughout their life, without an excessive amount of maintenance, within 10 per cent of their maximum power when new.

[2] Motor Rail-Cars, by Charles O. Guernsey.

Schedules Based on Careful Study

Schedule-making with the better organized companies is becoming a matter of detailed and painstaking study. The first step taken on the Motor Transit-Greyhound lines is to measure the length of routes accurately. Highway distances given by the published maps or route strips were found to be inadequate, possibly because of the special course the motorcoaches follow through cities and towns. So, to find the exact mileage, each route is carefully logged by a Greyhound traffic-department automobile. This is fitted with a hub odometer on each front wheel. Readings of the two are averaged to ascertain the station-to-station distances, as well as those in the open country and between county, city or town limits. The log shows where the type of highway changes, as the rate of speed allowed for varies with paved, gravel or dirt surfaces. A note is made of curves, sharp turns and railroad tracks, and of the traffic conditions in various cities and at different hours of the day.

With exact distances and road conditions known, the next step is to work out running times between sta-

tions. Average speeds are based on local regulations, size of towns and whether the towns have signal lights to control traffic. Good roads in open country may mean a speed of 40 m.p.h., this being reduced to 30 m.p.h. in small hamlets, 25 m.p.h. in towns having traffic signals, and to still less in congested cities. An allowance is made for comfort stops, meal stops and
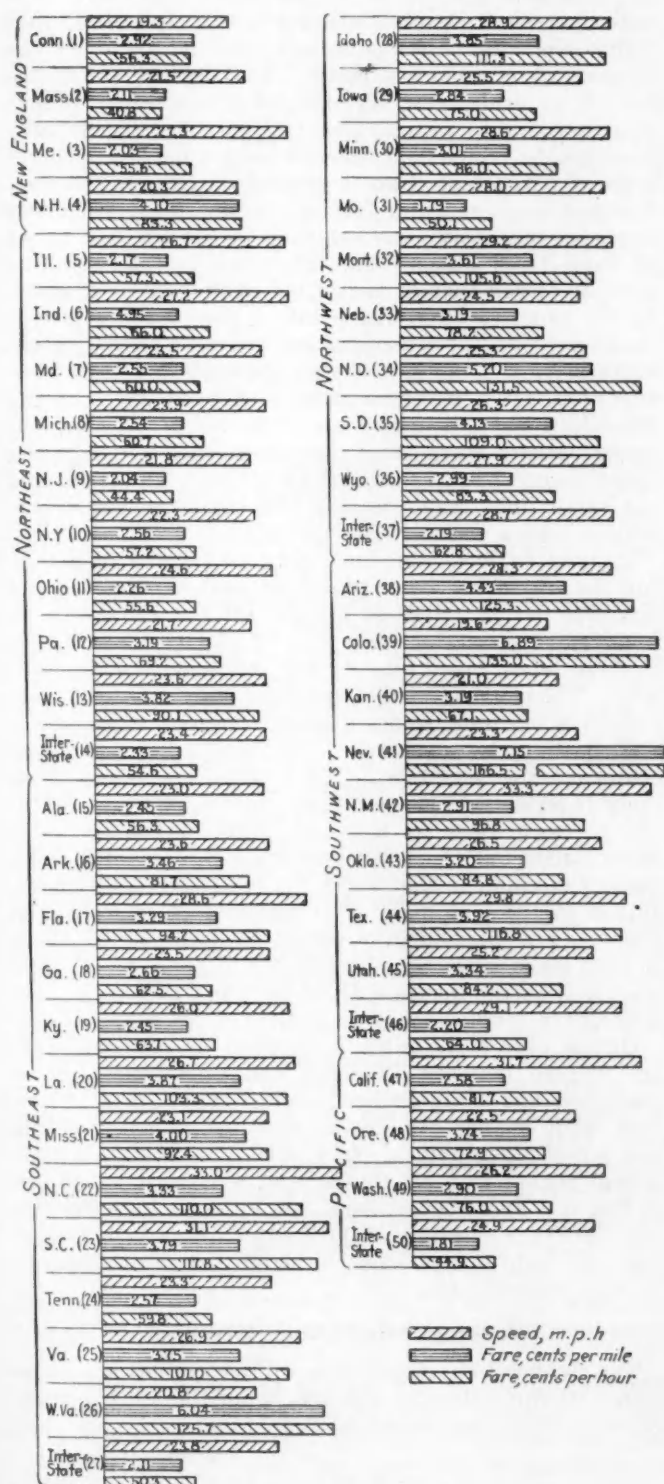

FIG. 12—CHART OF AVERAGE SPEED AND OF AVERAGE FARE IN CENTS PER MILE AND PER HOUR ON ROUTES THROUGHOUT THE COUNTRY

Route Numbers and Data Correspond with Those in Table 1

for station stops requiring more than two or three minutes to discharge and receive passengers. These stops can be curtailed somewhat between midnight and morning, thus reducing the running time. The station-to-station times, which are rounded off to the nearest 5-min. intervals, are totaled to give the through time for the route. The result is a tentative schedule, subject to change after it has been tried a few times by an experienced driver. After thus being proved, the schedule is ready to be printed and distributed to the public. It is then adhered to until operating conditions change so radically as to require its revision.

The printed schedules represent standard instructions for the driver, to be followed under all normal conditions. In emergencies he is supposed to do the best he can to keep to schedule without breaking speed laws to make up for delays. If the roads are bad on account of snow or mud, he must make his way through if it is humanly possible. He must drive around temporary blocks due to floods, landslides or to other vehicles, and look out for the comfort of passengers if the road proves impassable, finding shelter or other means of transportation for them. He must be able to make emergency repairs (Fig. 8), calling only as a last resort for company mechanics or for another vehicle, which may mean a trip of 100 miles or more.

A few operating companies have attempted to standardize the drivers' work beyond the printed schedule. The possibilities of further instructions are illustrated by the practices of the Santa Fe Transportation Co. on its route between Santa Fe and Albuquerque, N. M. These have met the approval of the New Mexico State Highway Department, which has advocated that the motoring public also follow them. Signs are posted with the following import:

Yellow circle—Come to stop, test brakes and descend hill in gear
Yellow rectangle, green stripe across center—Slow to 10 m.p.h.
Green triangle—Blind curve ahead; slow to 2 m.p.h. and sound siren
Purple diamond—Narrow road; stop when meeting opposing cars

Road supervision by a motorcycle patrol is being tried by the Motor Transit-Greyhound Lines. The men of the patrol follow the main routes and check drivers for speed and for observance of company operating-rules in general.

Vehicles Used and Possible Improvements

The equipment used on the long-distance lines ranges in size from a standard seven-passenger automobile, sometimes lengthened to carry 10 or 14 passengers, to the 40-passenger, two-engine type.

Standardization is essential from a consideration of passenger satisfaction. Travelers are not much concerned when they must change from one vehicle to another if they get the same kind of seat in another vehicle of the same type. Too often, however, the change is to a smaller vehicle or to one having a different type and layout of seats. This may be unavoidable when the transfer is to a vehicle of a different company but should not ordinarily be required on connecting routes of the same system.

Much improvement can be made in the seats for passengers who ride 24 hr. per day for several days. This applies to seat maintenance as well as construc-

tion. Heating and ventilating still remain troublesome problems. Drivers need to give more attention to adjusting windows with relation to prevailing winds, so that the minimum of dust will be drawn in and the maximum of fumes will be kept out of the interior. A standard kit of tools for light repairs should be available for each vehicle, as drivers must often make adjustments. Window curtains that can be adjusted vertically are desirable in open country where glare of the sun proves unbearable after a time. The vehicle lavatory and toilet are gaining somewhat in popularity, although it is questionable if they are used enough to justify the displacement of four seats.

The sleeper-type vehicle is being tried between Buffalo and Cleveland by the Great Lakes Stages, and a sleeping-coach service was started the latter part of June between Los Angeles and San Francisco with the Pickwick Nite-Coach. The future of this and other special services will depend on economic considerations more than on anything else. A higher charge than that made for a ride in a coach of conventional design is justified, and ultimately this should pay the cost of the special service. Extra-fare services have not made much headway, as few runs have enough business to support one class of service with ordinary equipment and another with more luxurious vehicles.

Fares Charged Vary with Conditions

Typical fares charged by the long-distance lines are shown in Table 1 and in the chart, Fig. 12. Like the statement in a prospectus, these fares "are not guaranteed but are based upon information which we believe to be accurate and reliable." The wide variation demonstrates the effect of interstate and railroad competition, poor roads and differences in the volume of passenger traffic. Compare, for example, the 7.15 cents per mile charged between Ely and Tonopah, Nev., on Route No. 41 having a tri-weekly service and the figures for Routes 2, 14, 27, 37, 46 and 50. The latter are sufficient proof of the low rates on long-distance interstate routes. Most of the rates average about 2¼ cents per mile. The effect of severe competition between passenger carriers, rail and road, is shown in the 1.8-cents rate between Portland, Ore., and San Francisco. Even this is higher than rates set at times by individuals or small companies operating between such centers as Chicago and St. Louis or Chicago and Detroit. In the winter, when business drops off, the fare per mile has been cut to as low as $3 for the 321-mile ride, or less than 1 cent per mile. The equipment and the service are much poorer than that of the companies collecting $5 for the trip.

Contrary to the uniform 3.6 cents per mile required for steam railroads unit motorcoach fares tend to decrease with the distance traveled, although not according to any set formula. Fig. 13 represents three long-distance tariffs or fare bases. The highest starts with 3.6 cents per mile and drops to 2 cents after 400 miles. This has been suggested as desirable by the head of a large Texas company, which actually is getting about 3 cents per mile for runs of about 100 miles and 2.84 cents for those of 500 or 600 miles. The middle curves of the two groups are based upon a Yelloway tariff between Needles, Calif., and Albuquerque, N. M. From Minnesota come the lowest fares, based upon 3 cents per mile for the first 100 miles and 2 cents per mile thereafter.

Distance alone cannot be taken as a guide in setting fares; volume of business over a given route must also be considered. On most main lines, local or suburban services of the operating company parallel the long-distance routes, and income from the two types of service helps to pay the total operating expenses. In principle, each run should take-in its direct costs and a reasonable proportion of all other expenses. The suburban routes probably are a necessary evil if they follow the main lines, although common facilities can be used at minimum expense. But if they are of the branch or stub-route variety and the revenue is low, joint ownership or management may be economically inadvisable. Suburban services should have a different type of equipment than is needed on the long routes. Revenue may go from bad to worse if, as sometimes happens, the short runs are used to get the last ounce of work from coaches that are obsolete for main-line service. Even though use of old equipment is justified by the small revenue, the public resents having to ride in old vehicles if better ones are operated in the neighborhood by the same company. A small operator, however, can often maintain the lower standard and has the additional advantage of much lower overhead expense. Hence many large companies prefer to have the short branch routes operated by others. The large and the small lines may well use the same passenger terminals, where connections can be made.

Combining local and long-distance service is a task for the operating department as well as one for the financial heads. Fig. 14 brings out the difference in requirements on the main line of the Oregon Stages System, lately taken over by the Southern Pacific Railway. The chart is plotted between daily one-way trips and miles of route, so the areas of the rectangles represent daily miles operated. Portland is the business center of the territory. Fifty trips are made from there to Salem, the Oregon State capital, 52 miles south. Six through runs to Klamath Falls, 394 miles, also serve Salem but the additional trips can be made with smaller equipment that lacks the baggage facilities required on the long run. The convenience of Corvallis, Eugene, and Roseburg is served by trips terminating at each place, although the number of these short runs decreases as the distance from Portland increases. Intermediate local service is indicated by dotted lines.

Of the 7428 daily miles, more than one-half, or 3834, are worked between Portland and Corvallis. Hence, operation and maintenance headquarters are at Portland, with smaller garages at Medford, Salem, Coquille and a few other points. In addition to this main line, lateral routes lead off to the east and west as shown in Fig. 3. These cover about 900 miles of highway but the coaches make only 6700 miles daily, which is less than the main-line mileage, although the route distance is more than double.

Passenger and Other Revenue

The financial characteristics of the system are illustrated by the following extracts from the 1927 reports of what were then separate companies:

	Miles Operated Annually	Average Passenger Revenue per Mile	Average Revenue per Passenger
Oregon Stages System	1,657,409	$0.252	$1.09
Pacific Stages, Inc.	871,338	0.293	0.67
Coast Auto Lines	650,994	0.156	1.53
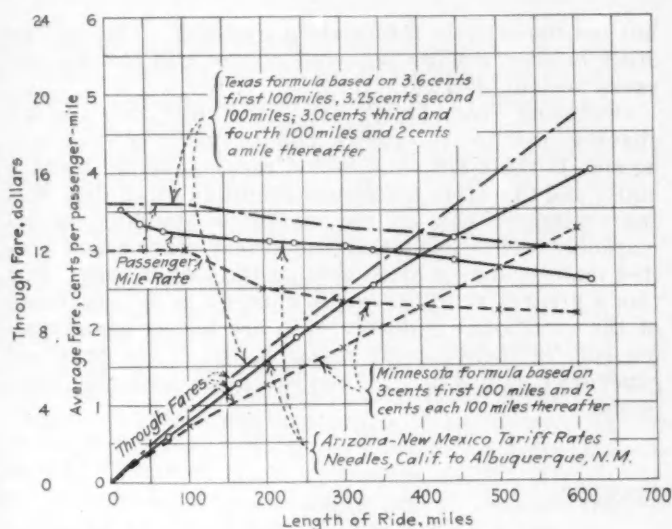
FIG. 13—METHODS OF CALCULATING LONG-DISTANCE FARES IN TEXAS AND MINNESOTA COMPARED WITH ACTUAL TARIFF CHARGED IN ARIZONA AND NEW MEXICO

During the period covered by these figures, the Oregon Stages System operated the main line from Portland to Medford, 317 miles in length. Pacific Stages covered 250 miles of routes in the northwestern part of Oregon, from Portland to Tillamook by way of McMinnville. The Coast Auto Lines had 420 miles of route in the southwestern part of the State, along the coast and eastward to connect with the Oregon Stages System. The three companies represent, respectively, long-distance service combined with local service in populous territory, suburban services out of a large city, and branch services in thinly-settled territory. Returns from mail and express are not included in figuring the revenue per mile. In the case of the Coast Auto Lines, mail revenue alone was about 30 per cent of that derived from passengers.

Express and newspapers bring in an appreciable revenue on many of the long intrastate routes. More and more of the interstate routes between the larger cities are handling these side lines. The quick delivery of small, light parcels has led a number of the intrastate passenger companies into the trucking business, with separate vehicles carrying freight only. A few lines have combination vehicles with a rear compartment for freight. One company in Kansas has developed its freight business in a little more than a year until it now gives overnight service to 75 towns, with daily outbound shipments of more than 100,000 lb. The largest interstate company has recently entered the field of long-distance furniture moving, with vans built upon chassis formerly used for passenger service. At present this work is handled on a contract basis. The next step may easily be the operation of trucks on regular routes and with fixed schedules.

These developments are not due to the long-distance passenger business having anywhere reached its limit. The Nation-wide merger recently announced has great potentialities, not only for economies in operation but also for improvements in service. Common terminals (see Fig. 11), will be a great help. Cooperative effort between this large operating group and the smaller long-distance companies and among the latter only, has

hardly begun. Arrangements for interline tickets based upon convenient connections are bound to grow in importance to the traveling public. Steam-railroad participation in this movement is increasing. The results have been satisfactory where it has been realized that highway services cannot be held down to the territory or practices of the steam-railroad owners.

Drivers and Manufacturers Deserve Praise

In closing this paper, a well deserved tribute should be paid to two factors that are largely responsible for the tremendous growth of long-distance lines within recent years. The first is the driver, the man who has the final responsibility for safe and comfortable transportation of passengers; the second, the manufacturer, as representing the suppliers of equipment. By a process of elimination which is rapidly sifting out the unfit and incompetent drivers, the operating companies have built up a personnel composed of men of superior personality and outstanding ability, both qualities being essential in the personally conducted tours which the drivers are daily piloting over thousands of miles of highway. I base this statement upon several years' observation, culminating in a recent trip behind 40 or 50 drivers, covering nearly 8000 miles of route from Illinois, Kentucky, and Tennessee as far west as California and Oregon.

On the trip mentioned, embracing many different routes and types of equipment, only two serious mechanical troubles occurred. The first failure was a
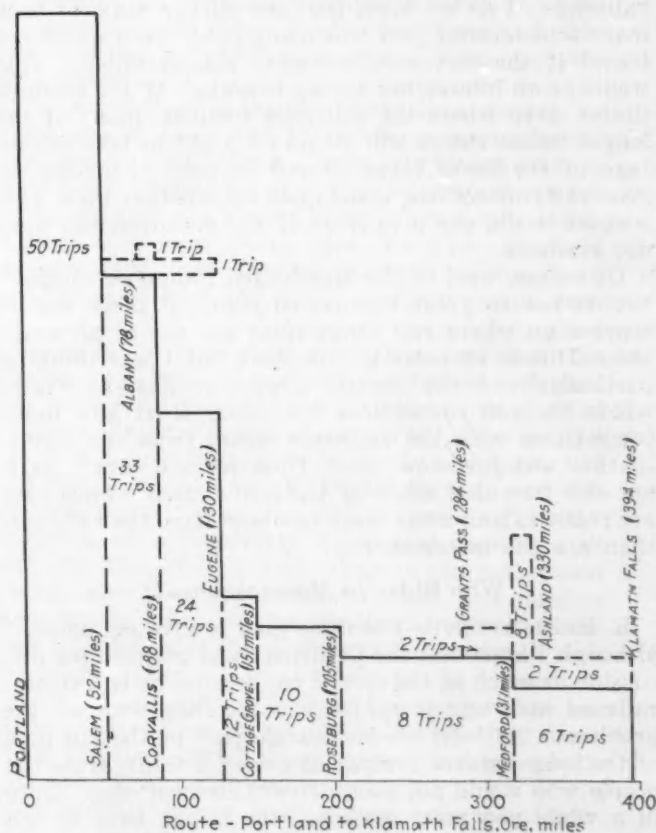
FIG. 14—FREQUENCY OF TRIPS ON ROUTES BETWEEN PORTLAND AND KLAMATH FALLS, ORE.

Area in Rectangles Is Proportional to Miles Operated per Day. Full Lines Represent Through Runs from Portland; Broken Lines Represent Intermediate or Local Services

broken right-hand front spring, which meant a delay while the new spring was brought from the nearest stockroom 100 miles away. The driver had removed the broken spring before the replacement arrived, so was only about 3 hr. late in completing his run.

The second trouble, in the engine lubrication system, was tinkered with awhile by the driver and a local garage mechanic. Finally, the former telephoned to the starting point, about 60 miles back, and another coach was sent out. The delay was about 3 hr., most of which was made up before the passengers completed the 660-mile trip. Two stalled vehicles were encountered on the road and their passengers taken on the one in which I was riding. One had a burnt-out coil and the other was out of fuel, according to the best

but not-too-reliable information available. One or two other engine troubles occurred on the trip but did not cause serious delays.

Operating companies are constantly demanding changes and improvements and probably always will do so. If their demands should cease, it would mean a static and therefore dangerous condition of affairs. But the equipment now on the market is standing up remarkably well, considering the severe service and limited maintenance it often gets on the longer runs. For this a great part of the credit must go to the engineers of the automotive industry, who are taking advantage, not only of their factory research, but of the practical experience gained on the road by all the operating companies.

THE DISCUSSION

A. J. SCAIFE[3]:—Regarding the so-called competition with the railroads about which we hear so much, is it not true that a great volume of this passenger traffic, which is secured by the different motorcoach companies, is really traffic that the railroads would not secure? That is, is it not true that many of the motorcoach riders on long-distance hauls use this means of transportation because of the low cost and that these riders would not travel by rail? Therefore, this business could not be considered as being taken away from the railroads. I do not know that any survey has ever been made to determine just how many passengers would not travel if the motorcoaches were not available. This would be an interesting survey to make. In the Eastern States, even where the railroads compete, many of the long-distance riders will sit up all night to take advantage of the lower fares offered between cities having good rail connections, and I question whether these passengers would use a railroad if the motorcoaches were not available.

Of course, west of the Mississippi I suppose competition is not so great because so many of these motorcoaches go where rail connections are not at all available. This is an entirely new field, but I was thinking particularly of the densely populated Eastern States where the rail connections are good. Just how much competition with the railroads comes from the motorcoaches and just how much from private cars? Is it not also true that many of the individually owned cars are really taking away more business from the railroads than are the motorcoaches?

Who Rides in Motorcoaches?

R. E. PLIMPTON:—I shall be glad to give my opinion, although I hope that the Chairman will get into the discussion as much as the rest of us, because he is a steam-railroad man and is thoroughly familiar with all the problems. At least a considerable part of the business of the long-distance companies comes, I think, from the people who would not even drive their own cars. Once in a while you meet someone who might have driven across country, but usually the passengers are people who would not think of making a trip of that length in

their own cars. Undoubtedly many who ride in the motorcoaches would have ridden in the day coach of the steam railroad. A smaller proportion are looking for adventure, are curious, or want to study this method of transportation and would otherwise have ridden in the Pullman on the steam railroad. I think that to a considerable extent the long-distance motorcoach is developing a new group of riders.

I am thinking of the crowd we met on the two long lines from Denver and El Paso to Los Angeles. We happened to come back at the time when travel was turning and people who had been out West for the winter were returning. Many had bought their return tickets and were using them. That is one of the great difficulties of motorcoach operation; keeping the vehicles going as they should in the winter is very hard. The operators have snow and other difficulties with which to contend.

The railroads are meeting this competition, or the competition of travel over the highway in general, by lower fares usually for a limited time. These low-fare trains have been tried out on the Pacific Coast for two years now and have been put into effect for summer operation between Chicago and the Pacific Coast. The general experience, as I have heard it, is that those very low fares simply bring out more new travelers who, for one reason or another, do not want to take advantage of the motorcoach. They are a little bit afraid of it, or do not want to take the time. Every increase in the facilities of travel and decrease in the rates seems to bring out a certain proportion of new riders. I do not say that all of this business is profitable; that is another question.

Rail, Air and Motorcoach Tie-In

F. C. HORNER[4]:—I should like to compliment Mr. Plimpton on the very comprehensive picture he has given us of long-distance motorcoach transportation and motorcoach transportation in general. I think he did an excellent job.

A situation such as we have here this morning, with a railroad man as chairman of a motorcoach transportation meeting of the Society of Automotive Engineers, is rather unique and shows the advance we have made in the matter of motor transport. Incidentally, Mr. Fritch, together with his associates in the Boston & Maine Railroad, are pioneers in the matter of tying in

motor transport with the railroad transport. To see Mr. Warner, who is noted for his experience and ability in airplane transportation, sitting in a motorcoach transportation meeting is also very interesting to me. I think he sees the tie-in of motor transport with the aircraft more clearly probably than any of us. You have to get passengers out to the field before you can transport them by aircraft, and from the field into town.

To emphasize the importance of motor transport, tied in with air transport, when I was in St. Louis at the meeting of the Motor Transport Division of the American Railway Association last winter, I lunched with a railroad man in the hotel and noticed fresh shrimp on the menu. I asked my companion if he thought it would really be fresh. He said, "Yes, it is not over 24 hours old." I asked, "How do they do that?" He replied, "They have seaplanes flying around between the little islands off the coast of Texas, near Galveston, picking up these shrimps, and flying them to the Houston airport. Then they are run in by high-speed truck from the airport to the railroad terminal, put on the Sunshine Limited, brought to St. Louis, and rushed from the airport to the hotels and markets. Inside of 24 hours after they are caught, you are having them served in the hotels at St. Louis."

Along the same general lines, that is what we have to do with passenger transport tied in with air transport, and which is developing very rapidly.

I had some observations made last summer and last fall on motorcoach transportation and found some very interesting things, many of which Mr. Plimpton has brought out. One that impressed me very forcibly was that the difference in cost between transportation by rail and motorcoach was from 30 to 40 per cent in favor of the latter. That is true in a large number of instances of rates of fare offered by various lines throughout the Country, which is of paramount importance to the rider in the motorcoach. These observations covered as far west as Omaha, the New England territory, south to Baltimore and the City of Washington and the eastern part of Canada. They showed that about 60 per cent of the riders were women. That was very interesting and indicated to me first of all that the women, usually having more time to spare than men, took the motorcoach in preference to perhaps the faster method of transportation, the railroad.

Need for Convenience and Safety

I know that in making some observations myself in New York City last August, at the Waldorf-Astoria station, where the facilities are very poor, they cleared 17 vehicles between 7:30 and 9:30 a.m. At times at least 100 people, men, women and children, with baggage and bird-cages and everything else, were standing around on the sidewalk in a little alley, in the utmost confusion, trying to find out where they were going, when the motorcoach left, and what they were to do with their baggage. I saw one woman with a baby in her arms stand in line for at least 15 min. trying to get a ticket. If people will ride in motorcoaches under those conditions, what will they do when the service is convenient and prompt and they can find out where they are going?

One of the most important things for us to consider is the matter of safety in operation. Entirely too many motorcoach accidents have occurred in the last six months, which indicates that not enough attention is being paid to safety. I am afraid many of these operators are keeping their men on duty too long, are running their vehicles too fast and not paying enough attention to the repair maintenance of the vehicles, especially the brakes. Driving a heavy motorcoach, or a light one for that matter, is hard work, and 8 hr. is long enough for any man to work at it. When a man drives a motorcoach for 10, 12 and 14 hr. at a stretch and at 40, 50 or 60 m.p.h., as many do, then his boss is forcing him far beyond safety limits. By comparing the operation of certain long-distance motorcoach lines in the East with some lines in the West, where accidents have been far too frequent, we have a picture that is striking and a lesson for motorcoach operators to study. When in Chicago, Omaha, St. Louis, Cleveland and Dayton, recently, I had time to go to several of the motorcoach terminals as a prospective passenger and ask questions. One of the points brought out, even by the men selling tickets on the vehicles, was that traffic had dropped off to some extent after the lines they represented had some of these bad accidents. To develop this or any class of transportation properly, and expand the use of the motorcoach, we must watch this accident problem carefully and continually.

What did Mr. Plimpton find out about the feature of riding through or stopping overnight? Was the tendency for motorcoach riders to stop overnight? I have had that question asked me a number of times, and am not well posted on it.

MR. PLIMPTON:—Mr. Horner stated that the reason for more women than men riding in motorcoaches is because they have more time. I was told by one man on the West Coast, who had a very good opportunity to see the situation, that the reason many women ride is because they have more nerve than the men. He said the women were more adventurous and willing to go out and travel without any men at all, as many of them do.

In riding in motorcoaches, the 90 per cent that ride for economy will keep on going just as fast as they can. Coming back from Los Angeles to Denver, we stopped at Williams, Santa Fe and Raton. That gave us two nights on the road and three nights in the hotel, but most of the passengers wanted to ride through and did. A few were taking their time, but I should say by far the majority on a long stretch like that would go all the way through, and perhaps 10 or 15 per cent would take even more than the 1400-mile trip. Any number of them would start in Chicago and go all the way through to the Coast. They seem to get hardened to it after a while. They sit up all night but have comfortable seats. They doze on and off during the day and night, and have 2-hr. stops during which they drink coffee all the time, which seems to revive them a little bit, but they keep on going.

MR. HORNER:—If you want to stop over and the arrangements are made, that is possible?

MR. PLIMPTON:—Yes. The tickets are sold on the basis that you can stop at any intermediate point that is a division terminal.

Preliminary Report on Fatigue Produced by Automobile Riding

By Fred August Moss, M. D.[1]

THIS IS a preliminary report of the results obtained to date in the study of fatigue incident to motor travel, which is part of the Society's Riding-Qualities Research program. A series of physiological tests were conducted after muscular fatigue had been induced by a known amount of work, with the hope of finding some tests sufficiently sensitive to measure less pronounced types of fatigue.

These fatigue tests conducted on subjects after riding showed that a decrease in the carbon-dioxide combining power of the blood and an increase in metabolism are fairly satisfactory indications of muscular fatigue, but the results led to the conclusion that the fatigue which accompanies riding in automobiles does not represent a very marked muscular fatigue, and suggested that it may represent a condition more closely similar to nerve fatigue. Consequently, a rather extensive study of various tests of nerve fatigue was undertaken.

It is proposed to make a further study of some of the more prominent tests with a view to selecting the two or three that are most valid, reliable, and easily administered. The research is being conducted by the Department of Psychology of George Washington University in cooperation with the United States Bureau of Standards under the auspices of the Society with funds subscribed by representative companies in the industry.[2]

PROGRESS in any line depends upon ability to measure exactly. The exactness of measurement is the best index of the development of a science. The steam engine could not be created until one man could make a piston and cylinder of dimensions sufficiently exact to prevent steam from escaping but to leave sufficient clearance for the piston to move up and down. The automobile had to wait until men could measure to the 1/5000th of an inch. Likewise, the improvement of devices for eliminating automobile riding-fatigue must depend upon measurement of that fatigue.

It has been well said that whatever exists at all exists in some amount, and anything that exists in amount can be measured. Fatigue and the other reactions that accompany long rides in automotive vehicles not only exist in amount, but today we are beginning to construct crude devices for measuring the amount.

Evolution is the essential characteristic of all attempts to devise reliable measuring instruments, and our present attempt, although only in its beginning, has gone through considerable evolution. We began by measuring the bodily changes which occur in muscular fatigue, the hope being that some of the tests for measuring these changes could be applied equally well to the measurement of the fatigue produced by long rides in automotive vehicles. There were two reasons for approaching the problem from this standpoint: first, it is rather definitely known that fatigue is basically a physiological phenomenon involving certain tissue changes and the accumulation of certain fatigue products in the body; second, if the physiological changes are sufficiently marked to be measured, physiological tests are quite definite and quantitative.

Physiological Tests of Muscular Fatigue

Before attempting to apply any of the physiological tests to measurement of riding fatigue, a preliminary study was made of the tests as applied to the measurement of fatigue brought about by a method known to produce rather marked muscular fatigue. The purpose of this preliminary experiment was to make a check on the tests themselves, a large number of tests being tried in the hope of finding some sensitive enough to measure the finer types of fatigue.

The method of producing muscular fatigue consisted in riding a bicycle ergometer, shown in Fig. 1. This machine, used by Benedict, consists of a bicycle frame and sprocket wheel, the rear bicycle wheel being replaced by a metal disc which turns through a magnetic field set up by an electric current passing through an electromagnet. By varying the strength of the magnetic field, regulated through a rheostat and ammeter, the amount of work performed in pedaling can be varied. The number of revolutions made is measured by an electric counter connected with the sprocket wheel. The speed and amperage used in the experiment were such as to make the work performed equivalent to about 0.16 calories per minute in terms of heat production.

The subjects were University men, none of whom at the time of the trials were accustomed to strenuous exercise nor regular exercise of any degree of strenuousness. On the third day of the experiment, each subject rode the bicycle for 15 min., making 70 r.p.m. against a current strength of 1.25 amp. This is equivalent to riding a bicycle at approximately 21 m.p.h. In the case of each subject, before and after fatigue, studies were made of blood pressure, pulse, carbon-dioxide combining power of the blood, blood sugar,

hemoglobin, blood counts, metabolism and respiration, urine (chemical and microscopic), chest expansion, strength of grip, and electrocardiograph records. On the first day of the experiment, normal metabolism and respiratory tests were made, and on the second day, normal electrocardiograph records were made. On the third day, another normal reading for metabolism was taken and normal tests were made of all the other items. The period of exercise followed these normal tests, and immediately afterward the fatigue tests were made.

The tests having been tried in measuring the strenuous muscular fatigue produced in the laboratory, the next step was the application to measurement of riding fatigue of those of the tests which had shown sufficient measuring qualities. The procedure in applying the tests in the second part of the study was as follows:

The same subjects who were used in the preliminary experiment were given a 250-mile ride under ordinary driving conditions over a moderately good hard-surface road. Tests of the subjects were made at the middle of the trip and at the end.

Description of the Physiological Tests

The physiological tests studied are described in the following paragraphs.

Blood Pressure.—Blood-pressure measurements show the response of the circulatory system to fatigue.

cent in diastolic pressure, and an average increase of 85.4 per cent in pulse pressure. Tabulations of all the changes in muscular fatigue are shown in Table 1.

Because in two of the ten cases the systolic blood pressure had fallen, while in all the others it had risen, further study was made of the blood-pressure results. Five subjects were exercised on the bicycle ergometer from 15 to 20 min. and their blood pressure taken at the end of each minute of exercise. Fig. 4 shows typical curves for three of the five subjects. In all the subjects the blood-pressure readings fall into a curve showing rapid rise to a maximum height, then gradual fall. The more enduring subjects seem to show maximum height of the curve at a later period. Onset of exhaustion seems to follow the downward slope of the curve. Thus, the two apparent inconsistencies probably represent only different stages of fatigue.

Blood-pressure measurements were also taken on the first road test, but the results were too inconsistent to be of much value. Blood-pressure measurements do not seem to show changes sufficiently sensitive to indicate the degree of fatigue produced in riding.

Metabolic Rate.—Metabolism tests measure the ratio of actual consumption of oxygen by the subject as compared with the amount he should normally consume. We know, from the increased breathing accompanying exercise, that fatigue increases the amount of oxygen
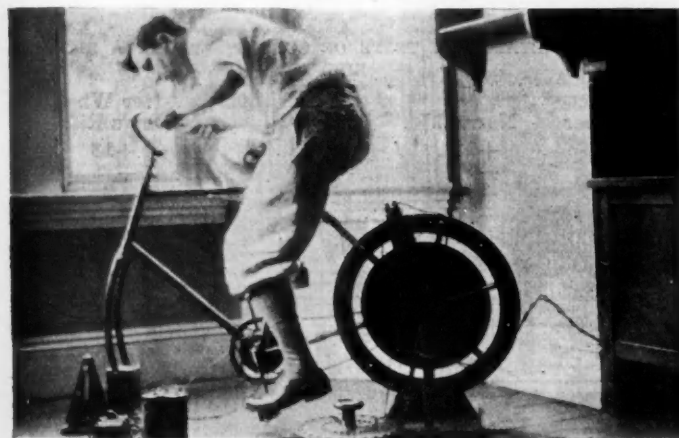
FIG. 1—THE ERGOMETER, USED FOR PRODUCING MUSCULAR FATIGUE OF A SUBJECT IN THE LABORATORY

FIG. 2—MEASURING BLOOD PRESSURE TO SHOW RESPONSE OF CIRCULATORY SYSTEM TO FATIGUE

Measurements were made of both systolic and diastolic blood pressure, and a record of pulse pressure was obtained by taking the difference between the two. The method of measuring blood pressure is shown in Fig. 2. Interesting changes in blood pressure were obtained after the severe fatigue on the ergometer. These were an average increase of 15.7 per cent in systolic blood pressure, an average decrease of 19.6 per

FIG. 3—METABOLIC TEST TO DETERMINE RATE OF OXYGEN CONSUMPTION BEFORE AND AFTER FATIGUE

consumed. A measurement of the amount consumed in a unit of time may perhaps give us a desirable measure of the degree of fatigue provided we know the normal amount the person uses. The apparatus, shown in Fig. 3, consists in an arrangement for having the subject breathe from a tank of oxygen, the amount consumed being measured by the fall of a line recorded on a revolving drum. A typical record of

TABLE 1—SUMMARY OF PHYSIOLOGICAL CHANGES AFTER MUSCULAR FATIGUE

(In terms of percentage)

Subject Number	Blood Pressure, Systolic	Blood Pressure, Diastolic	Pulse Pressure	Pulse Count	Metabolic Rate	CO_2 Combining Power of Blood	Blood Sugar	Respiratory Rate	Red-Blood-Cell Count	White-Blood-Cell Count	Polymorphonuclears in Blood	Lymphocytes in Blood
206	−23	−37	+ 13	+106	+ 36	−57	+ 4	+ 73	+15	+ 28	− 7	+ 21
207	−18	−27	0	+135	+137	−41	+ 9	+325	+ 5	+ 68	− 9	+ 21
208	+ 8	+23	− 5	+113	+ 58	−38	+15	+ 55	+ 4	+ 87	+ 9	− 24
209	+ 5	−37	+ 62	+102	+ 96	−50	+36	+ 83	+ 6	+131	− 7	+ 24
210	+18	−29	+ 89	+ 82	+ 40	−35	− 9	+ 66	+ 2	0	−13	+ 37
211	+14	−17	+ 64	+125	+ 56	−52	+22	+ 80	+ 6	+169	−29	+ 73
212	+23	−34	+137	+114	+ 15	−34	− 7	+ 27	+ 2	+ 19	+ 1	+ 5
213	+25	−31	+178	+123	+ 46	−43	+25	+ 33	+12	+ 45	−24	+ 36
214	+65	+13	+144	+122	+ 30	−33	−27	+ 0	+ 6	+153	+ 1	+ 21
215	+40	−20	+172	+105	+ 31	−41	+32	+ 45	+ 6	+ 13	−20	+116
Average	+15.7	−19.6	+85.4	+112.7	+54.5	−42.4	+10.0	+78.7	+6.4	+71.3	−9.8	+35.4
Median	+20.5	−28.0	+77.0	+113.5	+43.0	−41.0	+12.0	+60.5	+6.0	+57.0	−8.0	+22.5

metabolism before and after fatigue is shown in Fig. 5.

After fatigue on the ergometer, the metabolic rate showed an average increase of 54.5 per cent. Metabolism tests on these same subjects on a road test are shown in Table 2. As would be expected, the tendency is for basal metabolism to increase. The average increase was 7 per cent after a half day's riding, and 8 per cent after a whole day's riding. It may be noticed that the metabolism increases obtained here and in later trials are rather small; in fact, in some instances being no greater than the increases which might be obtained through such things as emotional stimulation. While this is true, the constancy with which the increase is found makes it significant. If only one person were used for the measurement, the change might be a chance change, but it is quite unlikely that such extraneous factors enter into the majority of a group.

Carbon-Dioxide Combining Power of the Blood.— The tests of carbon-dioxide combining power of the blood measure the ability of the blood to take up carbon dioxide, which is one of the most important of the bodily-fatigue products. As the body becomes fatigued and the blood is taxed with an extra supply of carbon dioxide, the combining power of the blood decreases. After definite muscular fatigue, all the subjects showed

FIG. 4—SYSTOLIC-BLOOD-PRESSURE CURVES FOR THREE SUBJECTS DURING 20-MIN. SEVERE EXERCISE

a marked decrease in the carbon-dioxide combining power of the blood, the average decrease being 42.4 per cent. Table 3 indicates the results in this test for the same subjects after riding. In all the cases except one

TABLE 2—METABOLISM TESTS OF SUBJECTS AFTER A BICYCLE RIDE

Subject Number	Normal	After Half Day's Ride	After Whole Day's Ride
206	+13	..	+18
207	−17	+ 9	+ 9
208	+ 9	+ 8	+20
209	− 1	..	+ 5
210	+ 4	..	+13
211	− 3	..	− 6
212	+10	+10	+ 6
213	− 8	+15	+17
214	+ 1	+ 9	+ 4
215	− 2	+ 7	0
A	−19	0	− 3
Averages	− 1	+ 6	+ 7

the blood shows some decrease in combining power. The average decrease was 15 per cent. While this shows a definite tendency to decrease, it is not certain without further trial whether the results are constant enough for final use in riding tests. Another disadvantage of this test for use in riding measurements is that, for accurate results, food must not be taken during the period preceding the test. Certain kinds of food very decidedly affect the carbon-dioxide combining power of the blood. However, the test is probably worth more investigation before discarding it as entirely non-indicative.

Other Blood Tests.—Other blood tests studied include white-cell counts, red-cell counts and blood-sugar changes. The cell counts show the number of the two types of cells in the blood per unit volume. White-cell counts, particularly, would be expected to increase. This measure is important because the white cells of the blood are its protective agents, being found in increased number when any poison is to be eliminated from the system. It was expected that blood sugar might show some change with fatigue, since blood sugar is the fuel material of the body. White-cell counts

TABLE 3—TESTS OF COMBINING POWER OF THE BLOOD AFTER DEFINITE MUSCULAR FATIGUE

Subject Number	Normal	After Riding
206	56	..
207	56	48
208	48	44
209	50	34
210	51	..
211	42	..
212	50	50
213	49	44
214	58	41
215	49	37
A	..	48
Averages	50.9	43.2

TABLE 4—WHITE-BLOOD-CELL COUNTS FOLLOWING 250-MILE BICYCLE ROAD-TEST

Subject Number	Normal	After Half Day's Ride	After Whole Day's Ride
206	8,250	10,500	6,800
207	7,150	8,850	15,000
208	8,000	6,000	13,200
209	7,250	11,150	.....
210	7,600	.....	7,100
211	5,200	.....	6,800
212	7,700	.....	15,000
213	6,800	.....	7,400
214	6,700	.....	7,600
215	7,350	7,700	7,350
A	....	7,800	....
Averages	7,200	8,683	9,583

showed an increase after marked muscular fatigue in every subject, as shown by a differential count, the tendency being for the polymorphonuclear cells to decrease and the lymphocytes to increase. The average increase in total white-cell count was 71.3 per cent. In red-cell count, the preliminary trial with muscular fatigue showed a slight increase. Blood-sugar results were not constant, the tendency being, however, to increase, as measured at the end of 15 min. work on the ergometer.

The explanation of this might lie in the fact that the subjects had reached varying stages of fatigue, strenuous exercise tending to increase the available blood sugar, and continued exercise in turn using up the increased or excess supply.

The red-cell count and blood-sugar test were not tried in road tests. The white-cell counts following the 250-mile road test showed the results given in Table 4. After a half day's riding the average of the white-cell
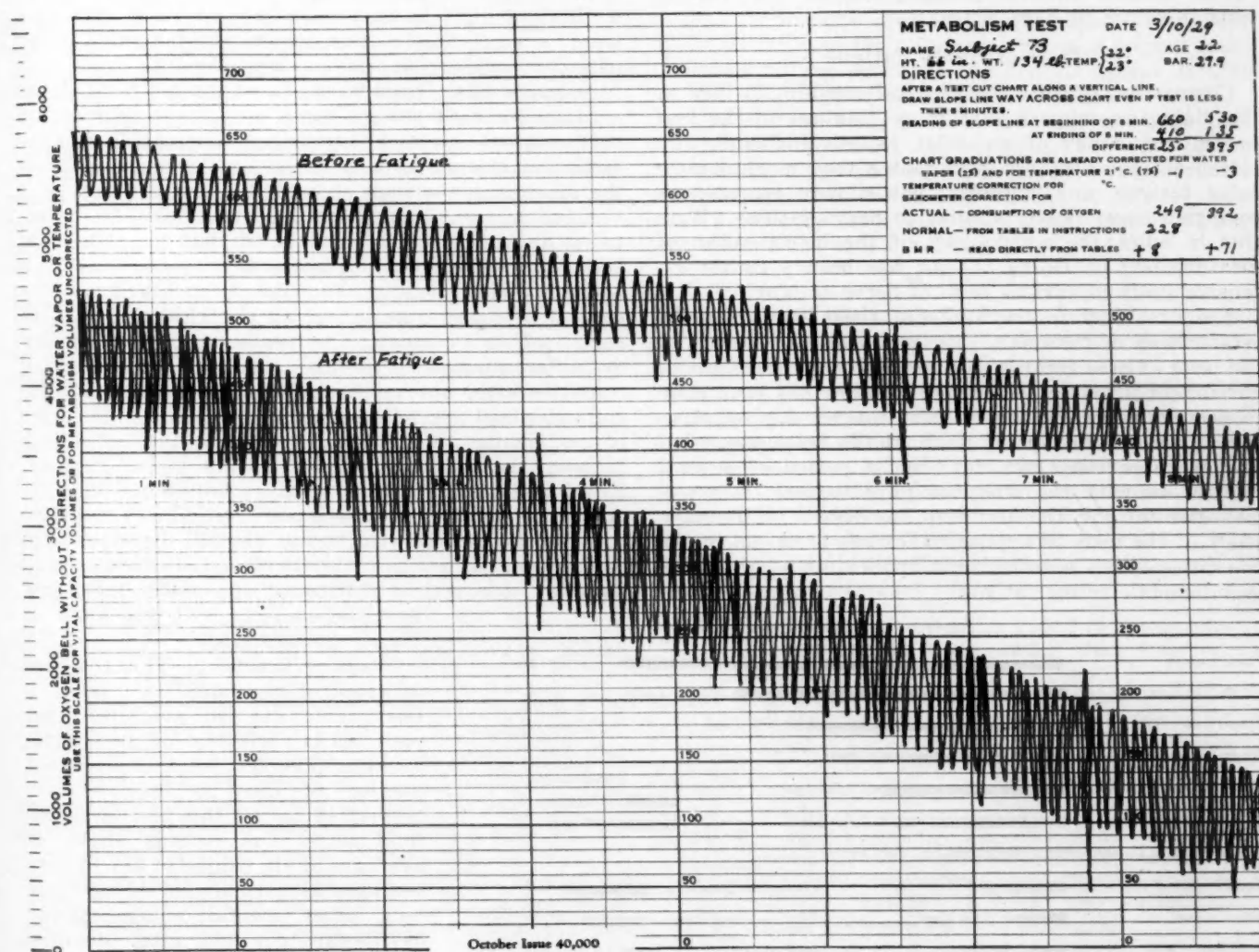
FIG. 5—METABOLISM RECORD FOR ONE SUBJECT BEFORE AND AFTER SEVERE EXERCISE

Note in the Lower Record, After Fatigue, the Longer Strokes Signifying Deeper Breathing, the Greater Number of Strokes Signifying More Frequent Inhalations, and the Greater Slope of the Curve Indicating Increased Consumption of Oxygen

counts showed a 20-per cent increase; and, after a whole day's riding, a 33-per cent increase. Although the averages show decided increase, the results are not very encouraging, because they show some lack of constancy, the amount of increase being quite variable from subject to subject and, in a few instances, the tests showing no increase. If used, the white-cell measurements must be carried on under very carefully controlled conditions, for, like carbon-dioxide combining power, the white-cell count varies with a number of other factors besides fatigue.

Electrocardiograph Records. — Electrocardiographs are graphical representations of the electrical changes accompanying heart-beat. To obtain these graphs, two leading-off electrodes were applied to the body, one to the right arm and one to the left leg. The electrocardiographs were made by photographing the movements of a galvanometer string on a film moving at known speed. This test was made after fatigue by riding the bicycle ergometer. Results were not sufficiently encouraging to make trial with automobile riding advisable.

The other physiological tests mentioned showed little of predictive interest and will not be described in detail.

The relative differentiating power of the various tests is shown in Figs. 6 and 7.

Tests of Nerve Fatigue

Comparison of the physiological results obtained in the riding experiment with those obtained in the first preliminary study of muscular fatigue indicates that riding fatigue does not represent a very marked muscular fatigue, and suggests that it may represent a condition more closely similar to nerve fatigue. With this in mind, the second part of the investigation of measurement of riding fatigue has been a rather extensive study of various tests of nerve fatigue.

The first step in the study of these tests was the establishing of "normals" for each subject on each of the tests. These records consist of performances under normal conditions after enough practice has been done to eliminate any increase in performance due to learning. To reach this point, each of the tests was tried two or three times per day over a period of several weeks. As with the study of physiological tests and muscular fatigue, the first step has been a preliminary study of the tests as applied to fatigue produced in the laboratory, with a subsequent application of the tests to automobile riding-fatigue.
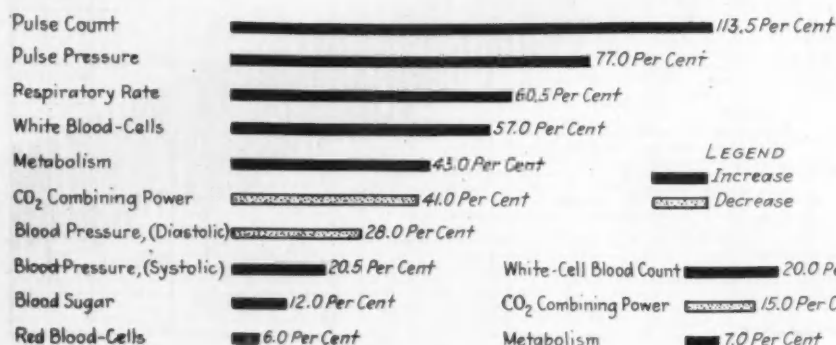
For the preliminary part of this portion of the study, a condition of nerve fatigue was produced by 5-hr. continuous mental multiplication. This consisted in multiplying two-place by two-place numbers, the problems being arranged in sets of 40 problems. As soon as a set was finished, the subjects were instructed to immediately begin another set. At the end of 5 hr., the various tests to be described were applied.

Road tests of the measurements of nerve fatigue consisted in their application after periods of automobile riding. Three road tests are reported. Two were made over moderately good hard-surface road, one consisting of approximately 250 miles of driving and the other of 300 miles. The third road test consisted in approximately 150 miles of driving over very rough dirt and gravel roads.

The tests used and the results obtained may be summarized as follows:

Number Checking.—The test used consists of sheets containing 1000 numbers, 100 of each of the 10 digits mixed together at random. Performance on the test is measured by speed and accuracy in crossing out all of a given number in a unit of time, 1 min. being used for each trial. In the tests made, each person's score is an average of 10 trials involving the crossing out of a different digit in each trial. The averages in scores were: normal, 66.15; after mental multiplication, 64.4; after 300-mile drive, 58.77; after 150-mile drive over poor roads, 64.6. Each of the three fatigue tests shows a fairly constant though not a very large decrease in performance. Another interesting thing about the results was that those who had done the major part of the driving on the trips showed the largest decrease.

Steadiness.—A motor test of steadiness was tried, using an apparatus so constructed that the individual was required to trace through a narrow groove with a stylus without touching the edges, as in Fig. 8. Every contact with the edge caused an electrical contact that registered on a counter. The results on this test showed no differentiation of normal condition and fatigued condition after automobile riding. The unfavorable results obtained are believed not to be entirely indicative of no change in steadiness with driving or riding fatigue; they probably are largely due to two factors: First, learning may have partly counteracted any decrease in ability, as insufficient preliminary practice was had before the road tests; second, the steadiness device used has not proved entirely satisfactory in construction, the results depending too much upon just how the contacts with the sides of the groove are made.

Speed of Reaction.—This is a test of speed of movement in tapping a telegraphic key so arranged that each tap is registered on an electric counter. The test records represent number of taps per minute. The method of taking this test is shown in Fig. 9. The records show, in averages of six subjects: 427.14 taps per min. as normal; 397.42 taps per min. after mental multiplication; 377.75 taps per min. after 300-mile drive; and 400.25 taps per min. after 150-mile drive over poor road; decreases in ability of 6.9 per cent, 11.5 per cent, and 6.3 per cent re-

Pulse Count	113.5 Per Cent
Pulse Pressure	77.0 Per Cent
Respiratory Rate	60.5 Per Cent
White Blood-Cells	57.0 Per Cent
Metabolism	43.0 Per Cent
CO₂ Combining Power	41.0 Per Cent
Blood Pressure, (Diastolic)	28.0 Per Cent
Blood Pressure, (Systolic)	20.5 Per Cent
Blood Sugar	12.0 Per Cent
Red Blood-Cells	6.0 Per Cent

LEGEND
Increase
Decrease

White-Cell Blood Count	20.0 Per Cent
CO₂ Combining Power	15.0 Per Cent
Metabolism	7.0 Per Cent

FIG. 6—MEDIANS OF PHYSIOLOGICAL CHANGES PRODUCED BY MARKED MUSCULAR FATIGUE

FIG. 7—AVERAGES OF PHYSIOLOGICAL CHANGES PRODUCED BY AUTOMOBILE RIDING

FIG. 8—TESTING MUSCULAR STEADINESS AS
AN INDICATION OF NERVE FATIGUE AFTER AN
AUTOMOBILE DRIVE OR RIDE

FIG. 10—"WABBLE-METER"
TEST OF EQUILIBRIUM AFTER
FATIGUE

FIG. 9—MEASURING SPEED OF REACTION
AFTER NERVE FATIGUE BY MEANS OF A TEL-
EGRAPHIC KEY

spectively for the three fatigue condi-
tions.

Mental Multiplication.—This consists
in multiplying two-place by two-place
numbers mentally without making any
figures except recording the answers.
Each problem is placed on a 2 x 5-in.
çard kept before the subject until he
obta.ns the answer, which is recorded on a record sheet.
The test record is the number of problems worked in
10 min. Mental multiplication after driving showed an
average decrease in speed of 19.4 per cent and an aver-
age decrease of 18 per cent in number of problems cor-
rectly solved per unit of time. Without exception, all
the subjects showed decrease in multiplying ability
after the road tests.

Motor Coordination.—Motor coordination and eye-
hand coordination have been measured by speed in
threading needles of a given size with a given size of
thread. The record represents the number threaded per
minute. The results were too inconstant to be worth
reporting.

Two-Point Threshold.—An esthesiometer with the
two points placed $\frac{3}{4}$ in. apart was used in the test. The
area of the skin used was the back of the wrist. The
subject must distinguish without visual aid whether
both points or only one point is touched to his wrist.
Each trial consisted of 20 contacts, approximately one-
half being made with only one point, and one-half with
both points. The records represent the number out of
the 20 judged correctly by the subject. Very little
effect of fatigue upon this type of sensory discrimina-
tion was noticed.

Equilibrium Test.—The test consists in ability to
balance on one's heels for 1 min. on a "wabble-meter."
The apparatus is arranged so that the subject has under
the ball of his foot a bar, as shown in Fig. 10, which, if
pushed down too far or allowed to swing up too far or
moved from side to side by the person's losing his
balance, makes an electrical contact and registers by
ringing a bell. The records represent the number of
contacts of this kind per minute. Measurements of
equilibrium by this balancing test showed a decrease in

ability in all subjects after riding, the
average increase in errors on the bal-
ancing machine being 80 per cent after
an all-day ride. This test seems to be
one of the most promising of the nerve-
fatigue tests tried, the results being
quite constant from subject to subject,
and the differences between normal reac-
tions and fatigue reactions being quite large. It also
has the advantage of being quickly applied.

Basal Metabolism.—Basal-metabolism tests, as pre-
viously described, were again made in this part of the
experiment. They showed an average increase of 12.4
per cent after mental multiplication; of 7.0 per cent
after a 300-mile drive over good road; and of 33 per
cent after a 150-mile drive over poor road.

Conclusions

Summing up our investigation to date, we feel that
we have not yet found the key to the mysteries of nerve
fatigue. We have, however, apparently found two re-
liable keys to the realm of muscular fatigue, and these
by-products alone are worth many times the effort and
money expended so far. It is hoped that in our future
work we can find as reliable a measuring device for
nerve fatigue as we discovered in the changes in car-
bon-dioxide combining power and blood pressure for
measuring muscular fatigue.

In more detail, our investigations to date may be
summarized as follows:

(1) Fatigue which accompanies riding in automobiles
is very largely nerve, rather than muscular,
fatigue.

(2) Muscular fatigue is fairly satisfactorily indicated
in the decrease of carbon-dioxide combining
power of the blood and in increased metabolism.

(3) Blood pressure shows a typical rise at first in
muscular fatigue, then a fall as exhaustion
sets in.

(4) The most promising measures of nerve fatigue
which accompanies automobile riding are tests
of equilibrium, mental multiplication, speed of
reaction, number checking, and metabolism.
These are being further investigated.

Aeronautic Engineering

Report on Aircraft Lighting

Progress of Lighting Committee's Work and the Test Equipment to Be Used

BEFORE discussing the work being carried on by the S.A.E. Committee on Aircraft Lighting, I should like to discuss briefly the general problem of lighting incidental to vehicular transportation. After a new method of transportation has been developed beyond the experimental stage, attention usually is next directed toward procuring an adequate lighting system to increase its scope of usefulness beyond daylight hours. At this point, inventive geniuses of the Country immediately come forward with thousands of solutions and the vehicle manufacturer is deluged with new and alleged better things to try out. Then comes an era of systematic investigation and research to determine the requirements for all conditions of service, after which it is relatively simple to work out standards of good practice within the limitations of equipment design.

Naturally, the more popular the field is—and I do not believe it would be a violation of confidence if I intimated that aviation is popular—the greater number of people there are who have definite ideas as to the best solution for the lighting problem. With some 15 or 20 different manufacturers now making, or contemplating making, lighting equipment for airplanes, competition for the relatively small volume of business involved will be quite keen; and, if we can judge by our experience in the automobile field, will lead to as great a diversity of types of equipment as there are interested individuals, without doing a great deal toward bringing about unanimity of opinion as to the best compromises to make, considering all the factors involved.

Lighting equipment usually is designed around some one individual's ideas, regardless of whether they be theoretical or practical, and very often without any appreciable knowledge of the inherent limitations of energy supply and those pertaining to the design of an adequate light source and its proper utilization. I believe that, if airplane operator, designer and equipment manufacturer will cooperate through the medium of some organized body such as the S.A.E. and deal with this problem in its fundamental aspects, a reasonably satisfactory solution can be worked out. However, such a solution probably will fall far short of the expectations of many and

will perhaps be entirely below the optimistic claims of inventors, who are ever hoping to invent a searchlight having the physical dimensions and energy requirements of a pocket flashlight, but capable of projecting a beam from New York to Los Angeles regardless of the earth's curvature, atmospheric conditions, or limitations of the human eye.

Like Automobile-Lighting Problem

I look at the problem of airplane landing-lights as being very similar to that of automobile head-lamps, more limited in some of its phases but less limited in others. In the early days of automobile headlighting, not more than 8 or 10 years ago in fact, there were several thousand patented devices each of which offered a complete and thorough cure for all of the lighting problems of the motorist. However, only a small handful would meet the most lenient type of lighting specifications that the industry felt desirable to evolve at that time. Today, there are only about two dozen head-lamps

SAMPLE SET OF TEST EQUIPMENT

on the approved list of all States, and, while each has incorporated in it the designer's idea of method, the lighting results of all are closely comparable and they all meet standard specifications, which are tremendously more strict and complicated than were the original ones. This condition has been brought about by car and equipment engineers getting together, through the Lighting Division of this Society, and dealing with the problem from the standpoint of lighting results rather than from the standpoint of methods of producing them. Originally there was a tremendous diversity of opinion as to the best form of headlight beam, but, after extensive service tests were made, with laboratory equipment rather than commercial devices, there was found to be a remarkable unanimity of opinion as to the type of beam which would give the best average results under all conditions.

It strikes me that we are now starting through this stage in airplane lighting. Fortunately, however, industry seems not only willing but insistent that the requirements for airplane lighting be analyzed and, if possible, recommendations or specifications be laid down before conditions become chaotic as a result of commercial ardor. Expressed opinion along this line resulted, some few months ago, in the appointment by E. P. Warner, of an Aircraft Lighting Committee of the Aircraft Division. At the outset, it was the consensus of opinion of this Committee that, before anything tangible in the way of recommendations could be worked out, some rather extensive investigation work would be necessary; not merely a series of tests under one set of conditions at one particular airport, but a test extended to include different types of planes, in various parts of the Country, under various seasonal and weather conditions. Enthusiasm was so keen for getting started that the several members volunteered to contribute different parts of the experimental equipment and various operating companies volunteered to use the equipment on different types of planes under various conditions, and to record such data as the Committee wanted.

A sample set of the test equipment, as worked out by the Committee, consists briefly of one landing-lamp which may be set in any position, remaining

Standardization Activities

Cooperation and Standardization

Industry Urged to Assist Committees in Formulating Standards for Further Savings in Production

THE PIONEERS of the automotive industry in America were the originators of coordinated standardization almost at the birth of the industry. Their foresight and spirit of mutual cooperation in making use of this new tool of industry, largely in the work of the Mechanical Branch of the Association of Licensed Automobile Manufacturers, and later of the Society of Automotive Engineers, were directly responsible in large measure for the unprecedented position the automotive industry holds today among all the industries of the world.

The attainment of worthwhile and representative engineering standardization requires the thoughtful cooperation of all branches, companies and men of the industry, all of whom are affected sooner or later to a greater or less extent by any well-regulated standardization program. The Society's Standards Committee provides a compact, competent organization. However, committees representing the industry must draft proposals for study and approval by the entire industry before suitable standards can be developed for the industry.

The industry cannot conveniently decide such matters in meetings—no auditorium is large enough to house such meetings; therefore the committees' work is submitted to the industry by direct correspondence and through the S.A.E. JOURNAL. The committees depend upon adequate replies by the industry in general as a necessary guide to completing their work. As much as possible of routine or "red tape" is eliminated to simplify procedure and to minimize the time required of the men in the industry for study of proposed standards. This system requires no traveling and relatively little time and expense to the men in the industry, other than the members of the committee, to review proposals and reply to inquiries and circulated reports. The Society spends directly from its own funds more than $25,000 annually to provide this means for reducing by approximately $840,000,000 the annual bill of the industry in producing and selling its goods. The successful execution of this vast work requires prompt and continued cooperation by the industry; otherwise much of the money spent in this work is wasted.

Modern industrial life is moving rapidly, since the World War, and what was two men's work is now required of one. All advantage should therefore be taken of well organized and recognized means for accomplishment with least effort and expenditure. The Society, which can only reflect the progress and prosperity of the vast industries it represents, is at times handicapped in its work by lack of responsiveness to its efforts to coordinate the industries' opinions and experience for the purpose of formulating and promulgating useful, representative standards.

Straight-Shank Drills and Machine Tapers

A condensed detailed report on standardization of straight-shank drills that was prepared by a representative committee for which the Society is a co-sponsor, was published on p. 180 of the Aug., 1929, issue of the S. A. E. JOURNAL, with the request that companies in the industry indicate which of the two proposals submitted is preferred as American Standard. Insufficient replies to this request had been received by the Society up to Aug. 19, notwithstanding virtually every manufacturer of mechanical products is a user of drills and should be vitally interested in any proper effort to reduce their variety and the cost of using so common a tool.

Similarly, two proposals for the standardization of tapers for use in machine-tools and their appurtenances were published on p. 240 of the March, 1929, issue of THE JOURNAL. The committee that prepared these reports is about equally divided in its choice of the proposals, and the only way to reach a decision is to have the industry itself indicate which would be desirable for a standard. Too few responses have been received, however. Meanwhile the Committee cannot proceed. Other tool-standardization projects are closely related to this project, and they in turn will be sloweddown until such requests, published in THE JOURNAL, or otherwise referred to the industry at large, receive more attention.

The Society serves as the channel through which the desired results can be accomplished. The industry, as represented by all the companies and other interests in it, alone can furnish the necessary technical information upon which proposals of committees can be based, and indicate whether the work of those committees is acceptable. It is very desirable that the industry cooperate more promptly and effectively in the study and formulation of engineering and manufacturing standards that directly affect it.

Non-Ferrous Metals and Alloys

Non-Ferrous Metals Division Prepares General Information on Die Materials and Rare Metals

THE Non-Ferrous Metals Division of the Standards Committee has decided to present certain information on non-ferrous metals and alloys which either is not ready for incorporation in specification form or does not logically represent a part of a specification. Readers' comments will be gratefully received.

Non-Ferrous Cutting-Tools and Die Materials

Stellite is a cast alloy containing about 45 per cent cobalt, 30 per cent chromium, 15 per cent tungsten, and small quantities of manganese, silicon, iron, and carbon. It has better red-hardness than has high-speed steel but is not so tough. It requires no heat-treatment to develop hardness and cannot be appreciably softened by overheating. It is used extensively in the automotive industry for cutting-tools and dies, but not as a part of automotive equipment. The whole tool may be composed of Stellite, or a Stellite tip may be welded to a less expensive shank. At present the price of stellite is higher than that of high-speed steel.

Cemented Tungsten Carbide is a sin-

tered product usually composed of tungsten carbide, 80 to 97 per cent, and the balance cobalt. The tungsten carbide usually is made separately in the form of minute particles which are mixed with metallic cobalt powder and pressed to the desired shape. The briquet so formed is then heated in a hydrogen atmosphere to a temperature high enough for the cobalt to sinter the tungsten carbide particles firmly together. The material so produced has a hardness approximating that of sapphire and a toughness suitable for many cutting-tool and die purposes. The red-hardness far surpasses that of any previous cutting-tool material. Cemented tungsten carbide is so expensive at present that small pieces are welded to inexpensive shanks in the manufacture of cutting-tools. Drawing-dies and other dies are usually prepared by mounting small pieces of cemented tungsten carbide in more substantial pieces of other and less expensive material.

Like Stellite, cemented tungsten carbide is used extensively in the manufacture of automotive equipment but is not a part of such equipment. Cemented tungsten carbide requires no heat-treatment to develop the hardness, nor can it be materially softened by overheating. Its use entails special precautions both as to tool design and operation.

Elkonite is another non-ferrous alloy which is used extensively in the manufacture of automotive equipment but not in the equipment itself. It is a mixture of tungsten and copper with or without some carbon. It is used principally for welding electrodes. Elkonite of several grades is made to fit different requirements. In all of the grades it is desired to maintain high electrical conductivity and high resistance to wear. It is also necessary to maintain high resistance to upsetting, both at ordinary and elevated temperatures. One grade of Elkonite has a compressive strength of 200,000 lb. per sq. in., a tensile strength of 55,-

000 lb. per sq. in., and a Brinell hardness-number of 225. Elkonite is a sintered, not cast, product. It is furnished in stock 3/16 to 1 in. square by 8 in. long; in rectangular pieces ⅛ to 1 in. thick with widths up to 3 in. and length up to 8 in.; and in rings up to 8 in. in diameter with width and thickness as required. Elkonite usually is used only as a facing or wearing surface, silver-soldered to a copper electrode. It is usually necessary also to water-cool.

Miscellaneous

Tungsten is used for make-and-break contacts in automotive ignition systems and incandescent lamps.

Wrought tungsten is used for contact discs. It is essential for best results that the purity be controlled, and it is also desirable to control the grain size. The cross-section of a tungsten rod from which contact discs are cut should show a minimum of 10,000 grains per sq. mm. A longitudinal section will reveal the fibrous structure caused by working below the recrystallization temperature. Contact points are made in five general forms:

(1) Plain rivets
(2) Rivets with shoulders
(3) Screw with head on contact end
(4) Headless screw
(5) Screw with head on thread end.

The thickness of the disc depends somewhat on the diameter. The following standards are suggested:

Diameter, ± 0.002 In.	Thickness, ± 0.002 In.
0.063	0.020
0.093	0.025
0.126	0.030
0.145	0.035
0.151	0.040
0.174	0.045
0.188	0.050
0.251	0.060

The tungsten discs are mounted to the steel screw or rivet by "brazing" with copper or other material, the op-

eration usually being performed in a furnace with a hydrogen atmosphere. Tungsten contacts are used in nearly all battery ignition systems and in some magnetos.

Filaments used in incandescent lamps described on p. 133, S.A.E. HANDBOOK, 1929 edition, are made of nearly pure tungsten. For most purposes a "non-sag" filament is required. This filament is made by so controlling the process of manufacture that large grains are formed in the filament when first heated to a high temperature in the lamp. Although these large grains make the filament softer when cold, they increase the sag resistance of the filament when heated to the operating temperature. It is not sufficient that the filament be composed of large grains, because the grain boundaries may be so disposed as to allow displacement of adjacent sections by producing the undesirable condition referred to as "off-setting." To avoid off-setting, the grain boundaries should not make right angles with the length of the filament, and to minimize sagging, the grains should be as long as several filament diameters. Not only have these difficult conditions been obtained, but also the same filaments are so tough, either hot or cold, that they withstand high-frequency vibration caused by the engine and any ordinary bump without breaking.

Platinum, alloyed with iridium, is used as a contact material in magnetos where the peak current to be broken exceeds 4 amp. Such magnetos are used especially for aircraft engine ignition. Because of the high price of the platinum-group metals, the contact surfaces are faced with discs only as thick as necessary for satisfactory operation.

The leading-in wires of incandescent lamps have about the same coefficient of expansion as glass and therefore make a vacuum or gas-tight seal. They consist of a core of iron-nickel alloy containing about 44 per cent nickel and 56 per cent iron, coated with copper.
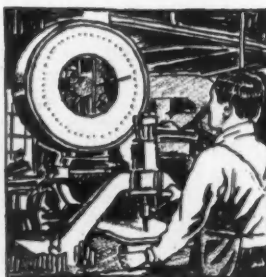
Production Engineering

Tungsten-Carbide Tools

Descriptive Bibliography of Trade-Paper Articles and Data from S. A. E. Meetings

TOOLS made from the recently developed forms of tungsten carbide were discussed at two meetings of the Society during last season, as reported in the news columns of the S.A.E. JOURNAL. One of these was the Nov. 7, 1928, meeting of the Milwaukee Section, at which Dr. S. L. Hoyt, of the experimental department of the General Electric Co., gave an address on Carboloy. The other was the closing session of the 1928 Production Meeting in Detroit, at which G. N. Sieger, of the Carboloy Co., discussed the same subject, and C. R. Burt, of the Pratt & Whitney Co., reported some observations he had made on Widia tools in Germany and on samples he had brought back with him. These meetings were reported in the S.A.E. JOURNAL for December, 1928, pp. 642 and 634. Neither of these meetings, however, resulted in a formal paper for publication in the JOURNAL.

Dr. Hoyt said that metallic tungsten powder, which has long been used in the incandescent-electric-light industry, is the starting point in making Carboloy. This is produced from oxide by reduction in a hydrogen furnace, and can be converted into tungsten carbide by mixing with the correct amount of carbon and heating the mixture to a suitable temperature and for a suitable time. Cobalt powder is mixed with the carbide, and the mixture is formed into a bar by hydraulic pressure in a steel mold. The material is rather friable in this form, and it is sintered at a red heat to make it strong enough for handling and shaping operations. A second sintering operation after forming results in the maximum hardness of the material. This hardness is permanent; the temper cannot be drawn, like that of steel. The combination of tungsten carbide and cobalt is a contribution of the German Osram Lamp Co.

No water has been used in the General Electric Laboratory in grinding Carboloy tools, and cutting ordinarily has been done without a coolant. Overheating should be avoided in grinding, and the tool should neither be sprayed nor dipped in water. A flood of oil has been used successfully in machining phosphor-bronze bushings with Carboloy, and a flood of water that will keep the tool at room temperature may be advisable on some jobs.

An example of the size of tool required was given by Dr. Hoyt, who said that a ⅜-in. cut could be taken in nickel steel with a 1/18-in. feed, using a Carboloy tip ½-in. wide and 1 in. long, copper-brazed to a shank 1¼-in. square.

In the discussion of Dr. Hoyt's address, the speaker was asked whether a principal use of tungsten carbide might not be to produce an excellent finish, provided the material can take a sufficiently keen edge and maintain it with so little wear that sizes can be held accurately. Dr. Hoyt replied that Carboloy will take an edge that appears quite keen to the naked eye and to the finger, but microscopic examination shows it to be faceted. Examination of a diamond tool, which gives a bright, polished finish on monel metal, also shows facets at the edge, so it seems to Dr. Hoyt that a very keen edge is not necessary in producing a smooth finish.

The introduction of Carboloy was said by Mr. Sieger, in his Production Meeting paper, to promise an extension of the field of usefulness for other materials rather than to threaten to displace them. For instance, Stellite and manganese steel can be machined with Carboloy, as they could not be with materials previously available.

Bibliography of Tungsten-Carbide Tools

Following is a list of articles that have appeared in the trade press in this Country on the subject, with brief descriptions of their contents. E. C. Howell, of the Dauchy Co., New York City, assisted in preparing the list.

Imported Alloys Replace Chilled Iron in Drawing Dies; by M. Simons, Union Wire Die Corp. *Wire and Wire Products*, October, 1928, p. 331. Records the use of Widia and Wallramite in dies, increasing the production of wire-drawing machines by at least 20 per cent.

Hardened Steels Are Machined with New Cutting-Tool Materials. *Automotive Industries*, Oct. 20, 1928, p. 560, illustrated. Reports paper on Carboloy read by Dr. S. L. Hoyt, of the Research Laboratory of the General Electric Co., at a meeting of the American Society for Steel Treating and gives information on the results of using Carboloy tools for experimental and production machining operations on glass, manganese steel, chilled iron, molded materials and other substances. Also in *Machinery*, November, 1928, p. 214.

A Successful Product May Find Use in Many Industries; editorial. *Engineering and Mining Journal*, Nov. 3, 1928, p. 697. Suggests the possible use of "borium" as a substitute for beaters and Jordan mills for shredding wood and other fiber into pulp.

Kilo-Man-Hour Proposed as Gage of Manufacturing Efficiency; by K. W. Stillman. *Automotive Industries*, Dec. 15, 1928, p. 868. Briefly reports paper on Carboloy presented by Dr. Hoyt, of General Electric Co., at the Annual Meeting of the American Society of Mechanical Engineers, and remarks by C. R. Burt, of the Pratt & Whitney Co., at the S.A.E. Production Meeting on his observations of Widia in Europe and America. Practices in grinding-tools and the size of chips were indicated by Dr. Hoyt, and reports of cuts, feeds and speeds were given by Mr. Burt.

Carboloy Described. S.A.E. JOURNAL, December, 1928, p. 642. Reports reading of paper at the Milwaukee Section of the Society by Dr. S. L. Hoyt, describing the methods of producing Carboloy tools and the work done in the development of their use. Machining materials like manganese steel and Stellite is classed as a stunt.

What May Be Expected from Carboloy. *Machinery*, January, 1929, p. 353. Detailed report of Mr. Sieger's paper at the Production Meeting of the Society, telling of the use of Carboloy as a substitute for diamonds for certain purposes. Increased production when Carboloy is substituted for steel is secured by high cutting-speed.

Tungsten; by Frank L. Hess. *Engineering and Mining Journal*, Jan. 19, 1929, p. 99. Gives a brief outline of the process of making tungsten-carbide and mentions the effect of its use on the tungsten market.

Carboloy and Tungsten-Carbide Tools; A.S.M.E. Paper, by Dr. Samuel L. Hoyt, General Electric Co. *Machinery*, February, 1929, p. 457. Describes properties of tungsten carbide and tells of materials for tool shanks; methods of preparing, brazing, grinding, and lapping; and its use for machining metals and other materials. The probable field for the use of tungsten carbide and its effect on machine-tool design are also touched upon. Also in *American Machinist*, Jan. 10, 1929, p. 47; *The Iron Age*, Dec. 13, 1928; and *Iron Trade Review*, Dec. 13, 1928, p. 1503.

Tungsten-Carbide Cutting-Tools. *The Iron Age*, Feb. 7, 1929, p. 429. Gives a list of various brands and makers of tungsten-carbide tools and mentions several other related materials.

Standard Tungsten-Carbide Tools. *American Machinist*, Feb. 7, 1929, p. 255; and Feb. 14, 1929, p. 295. Outline drawings of general-service tools as recommended for Widia metal by Thomas Prosser & Son.

Tungsten-Carbide Tool Efficiency; by George S. Brady. *American Machinist*, Feb. 28, 1929, p. 346. Reports a break-down test and several other tests conducted at the Philadelphia Navy Yard to determine the

saving in grinding time and power consumption and the ultimate possibilities of tungsten-carbide tools.

Grinding Tungsten-Carbide Tools; by A. H. Prey, Carborundum Co. *The Iron Age*, Feb. 28, 1929, p. 599. Recommends grinding in three operations and specifies grits, bonds, wheel speeds and cooling conditions for off-hand grinding. Also in *Iron Trade Review*, Feb. 28, 1929, p. 590; *American Machinist*, March 7, 1929, p. 404; and *Machinery*, March, 1929, p. 536.

How Carboloy Will Affect Tool Design; A.S.M.E. Paper by E. G. Gilson and G. N. Sieger. *Machinery*, April, 1929, p. 613. Tells of special provisions needed in the way of firm tool-support, power, design and lubrication of bearings and tail-stock, and use of coolants. Also in *Iron Age*, April 4, 1929, p. 948; and *Iron Trade Review*, April 25, 1929, p. 1115.

Effect of Tungsten-Carbide Tools on Machine Design; A.S.M.E. Paper, by M. E. Guild. *Iron Trade Review*, April 25, 1929, p. 1115, illustrated. Shows heavy machine-tools developed by Krupp. Gives forms of tools for various purposes and data on feeds and cuts and tool pressure in different materials.

Tungsten-Carbide Tools for Production Work; *Machinery*, April, 1929, p. 621. A compilation of information from leading automobile and machine-building plants on the results obtained with tungsten-carbide tools, including cost, speed and savings in definite cases where they have replaced steel and diamond tools. Grinding recommendations are included.

Development and Application of Widia; A.S.M.E. Paper by R. D. Prosser. *American Machinist*, April 11, 1929, p. 587, illustrated. Includes outline of development by the Krupp works, results obtained in automobile and other factories in cutting both ferrous and non-ferrous metals, and other information on the tools and their use. Also in *Machinery*, May, 1929, p. 692.

The Use and Abuse of Carboloy; by Emery G. Gilson. *American Machinist*, May 2, 1929, p. 699, illustrated. Explains precautions necessitated by brittleness of the material, requirements of tool shanks and recommendations for form of cutting-tools. General directions and warnings as to grinding are given.

Status of Tungsten-Carbide as a Cutting Material; report of A.S.M.E. research committee. *The Iron Age*, May 16, 1929, p. 1349. Brands of tungsten-carbide tools are enumerated. Several instances of use are described in detail, and machine-tool requirements are listed. Also in *American Machinist*, May 30, 1929, p. 865.

Tungsten-Carbide Cutting-Tools; A.S.M.E. paper by H. J. Long and W. P. Eddy, Jr., Brown-Lipe-Chapin Co. *The Iron Age*, May 23, 1929, p. 1414. Experiences in mounting tool tips and grinding are recorded. Successful applications in cutting malleable and grey cast-iron and alloy steel are recounted, also several unsuccessful applplications, including uses on automatic machines where the tool support was not rigid. Also in *Machinery*, June, 1929, p. 783; and *American Machinist*, June 6, 1929, p. 901.

German Practice with Tungsten-Carbide Tools; by Dr. George Schlesinger. *American Machinist*, July 11, 1929, p. 37, illustrated. Includes a table showing chemical composition and methods of manufacture of various tools and curves showing the life of a number of different tools tested at various speeds. Recommended tool forms and cutting angles are given. Cutting pressures are indicated by diagrams and tables. A roller-bearing machine-arbor mounting is shown that has been successful at two or three times the ordinary speeds of machine-tools.

A User Tests Tungsten-Carbide Tools; by F. S. Walters. *Machinery*, August, 1929, p. 934. Results obtained in laboratory tests by a large unnamed manufacturing concern are given. They include tests on iron, molded materials and marble and intermittent cuts in commutators and cast-iron.

Live-Center for Use with Tungsten-Carbide Tools. *The Iron Age*, July 25, 1929, p. 223. Describes an anti-friction-bearing live-center offered to replace the dead-center of a lathe.

Aeronautic Engineering

fixed in this position when the machine is in the air; one landing-lamp which can be aimed through an angle of 90 deg. at the will of the pilot, presumably so mounted as to be capable of having its beam directed straight down or straight ahead, or at any desired angle between these limits. The beam from either of these units may be modified to meet the desires of the engineer or pilot in charge of the test. Some of these variations are produced by changing the focus of the lamp; others by the use of spreading lenses, samples of which are shown. With this equipment it is possible to produce beams varying in spread from 10 to 50 deg. either vertically or horizontally.

In addition to the lighting units, there is included in each set of equipment all of the necessary auxiliary devices such as lamps, batteries, generators, wiring and switches.

It is contemplated to keep two records of all tests, an *A* and a *B* record of details. The *A* record records all data essential to a particular installation and is filled out by the engineer in charge of the test. The *B* record is a pilot's daily-report sheet of how much the equipment was used, for what purpose, and his impressions. From data included in the engineer's report, it will be possible at any future time to duplicate the lighting results of any particular test for purposes of making photometric measurements of the beam.

One complete set of the equipment is to be supplied to each of the following companies: Boeing, National Air Transport, Pitcairn, Stout, and United States Army. The Committee hopes to have this equipment in the hands of the various companies making the tests within the next few weeks, and that they will actually begin collecting test data before the summer is over.

Undoubtedly, when tests are started many new problems will develop which have not occurred to the Committee as yet, and they will have to be dealt with in such a way as not to curtail our effort in obtaining essential data. If enthusiasm on the part of the operating companies making the tests remains as good as that evidenced at our previous meetings, and if there are not too many unanticipated delays, the Committee should have in its hands, within a few months, at least enough data to determine if there is any one system of lighting which will, to a reasonable extent, meet the varied requirements of this service, and whether simple and workable specifications can be formulated as a guide to equipment designers.

W. M. JOHNSON, *Chairman*,
Lighting Subcommittee.

Where Keally Paper Was Given

ARCHITECTURAL Treatment of Airports was the subject of a paper by Francis Keally, which was printed in the S.A.E. JOURNAL for August. This was erroneously described as a Metropolitan Section paper. It was presented at a recent meeting of the Pennsylvania Section in Philadelphia.

Transportation Engineering

Making Tire-Type Changes

Care to Be Taken When Substituting Motorcoach Balloon and Motor-Truck Pneumatic Tires

CONSIDERATIONS involved in regard to the substitution of high-pressure pneumatic tires for solid-rubber tires on motor-trucks, and of balloon tires for high-pressure pneumatic tires on motorcoaches, were presented at Portland, Ore., by J. W. Stavely, of the Firestone Tire & Rubber Co., Akron, Ohio, at the first official meeting of the Northwest Section. The author discussed tire sizes, pressures and loads and enumerated the factors that govern decisions as to whether changes of tire type are desirable, conditions affecting dual-tire usage, and the changing of motor-truck wheel-equipment to provide for the substitution of pneumatic for solid-rubber tires.

Tire Sizes, Pressures and Loads

According to Mr. Stavely, the rule is generally accepted that the best service is obtained from high-pressure pneumatic motor-truck tires when the load is such that the deflection of the tire does not exceed 14 per cent of the cross-section. With motorcoach balloon-tires, a maximum deflection of 18 per cent is the limit; high-pressure and balloon passenger-car tires may deflect 15 and 21 per cent respectively. Keeping these limitations in mind, the maximum recommended load-carrying capacity of a tire is, roughly, the product of the air pressure and the area of contact of the tire with the road. The area of road contact is mainly determined by the diameter and cross-section of the tire and the tread contour. Hence, if it were desired to substitute a tire designed for high air-pressure by a low-pressure tire, it would be necessary to increase the area of contact of the tread with the road, and this might necessitate an increase in tire section. That is exactly what happened when the balloon tire was designed to replace the high-pressure tire.

High-pressure pneumatic tires for motor-trucks are designed for 20 and 24-in. wheels. The recommended load and inflation pressure for these tires are listed in the accompanying tabular statement.

Balloon tires for motorcoach and motor-truck service are made in 20 and 22-in. diameter and call for an inflation pressure of 50 to 75 lb. per sq. in. The motorcoach balloon-tire has established itself in the transportation industry, and the fact has been proved that in-creased riding comfort can be obtained without sacrificing tire performance. The motor-truck balloon-tire is less widely used, and the choice of this type of equipment is largely a matter of the requirements for specific types of service.

Large motorcoach fleets equipped with motorcoach balloon-tires have been operating on the Pacific Coast for the last three years. The operators have found that this type of tire equipment reduces maintenance, causes fewer road delays and gives increased satisfaction to the passengers. For a time some opposition existed to motorcoach balloon-tires for stage equipment, as some operators feared that the occurrence of a flat tire at high speed might constitute a hazard; but the fact has repeatedly been proved during the last three years that no greater hazard results from flat tires with motorcoach balloon-tires than with high-pressure tires. Whereas, a year or more ago, the 8.25 balloon-tire was the most popular, we find that today the 9.00 and the 9.75 sizes are being used in the greater numbers.

Substituting Balloon for High-Pressure Tires

The substitution of motorcoach balloon-tires for high-pressure pneumatic tires does not require a wheel change if the wheel diameter is 20 in., but a wheel change is necessary if the rim diameter is 24 in. For example, a 9.00-20 motorcoach balloon-tire will fit on the same wheel and rim equipment as will a 34 x 7-in. high-pressure tire and will provide an increased carrying capacity of 200 lb. per tire. The over-all diameter of the 9.00-20 tire is 2.1 in. greater than that of the 34 x 7-in. tire but, because the 9.00-20 tire deflects 18 per cent of its cross-section and the 34 x 7-in. tire only 14 per cent, the actual difference corresponds to 1 in. in diameter, or about 3 per cent. This would result in a small loss of power, but it also permits greater speed. Actual practice shows that the loss in power is less than would normally result from a change in gear ratio, probably because the low-pressure tire is in contact with the ground a greater percentage of the time.

Use of the larger tire requires slightly greater body and fender clearance than does the smaller tire. It is also necessary to make certain that steering-rod arms, brakes, toggles and the like have sufficient clearance. If dual-tire equipment is used, it is also necessary to consider the clearance between the two tires, as the larger tires require more clearance here than do the smaller high-pressure tires. Clearance between the tires is usually referred to as "dual spacing"; it is the distance between the center of the treads of the outside and the inside tires. As a rule, the dual spacing is not a major drawback to change of tire type, although spacer rings are used occasionally.

Conditions Affecting Dual-Tire Usage

The mating of dual tires involves such variables as tire wear, pressure build-up and road crown. The first can be controlled to a certain extent by following the practice of mating tires that show the same amount of wear. New tires should be mated, and worn tires should be mated according to the amount of wear; but new tires and worn tires should not be mated, because the over-all diameter of a new tire may in some cases be less than that of a tire which has been in service. Fatigue of the fabric with service results in an increase in cross-section and over-all diameter of the tire; but, counteracting this increase, is the decrease resulting from tread wear. These differences probably are less in high-pressure pneumatic tires than in motorcoach balloon-tires.

Under operating conditions the inside dual tire usually carries more load than the outside tire. As a rule we increase the inflation pressure if we desire to increase the carrying capacity; but, in this case, increasing the pressure of the inside tire would raise the outside tire

Tire Size, in.	6	7	8	9	10
Rim Size, in.	6	7	8	9	10
Load for 20-In.-Diameter Wheel, lb.	2,200	2,800	3,600	4,500	5.500
Load for 24-In.-Diameter Wheel, lb.	2,500	3,200	4,000	5,000	6,000
Air Pressure, lb. per sq. in.	90	100	110	120	130

and throw more load on the inside tire. Lowering the pressure on the inside tire is undesirable; therefore the only alternative is to increase the pressure on the outside tire. However, we find that, in service, the pressure in the inside tire increases to a greater extent than does the pressure in the outside tire. This again throws the inflation adjustment out of balance and it is impossible to determine what excess pressure should be carried in the outside tire. As yet no generally accepted simple and reliable device is available for equalizing the pressure between outside and inside dual pneumatic tires.

Changing from Solid to Pneumatic Tires

Increasing legislation against solid-tire equipment makes a change-over to pneumatic-tire equipment desirable in some types of service. Many operators are finding that pneumatic-tire equipment reduces their operating costs as a result of increased speed and lower maintenance costs. More progress has been made with tire-type change on the Pacific Coast than in the East, probably because the average daily mileage of a motor-truck in the West is about twice that prevalent in the East. The substitution of pneumatic for solid tires is easier in the West, because the axle equipment is better standardized and wheels are more readily available. Either the wheel equipment can be changed or the steel wheels can be cut down and new felloes welded on.

We are informed that approximately 390 kinds and types of axles are in service, which complicates wheel changes considerably. The practice employed in cutting down steel wheels is to machine the spokes to the proper length, shrink-on a cast-steel felloe-band and weld it in place. If the spokes are cut with a torch, they should be left somewhat longer than necessary and then machined to the correct length to assure a strong weld.

Proper tire clearance is just as important in this case as for changes from high-pressure to balloon-tire equipment. The use of 24-in. tires is advisable wherever possible, as this will often avoid trouble that might arise from insufficient brake-drum clearance. The minimum clearance of the tire with the nearest point of interference should be 1 in. The tires should not extend beyond the fenders nor rub against them when the springs are fully deflected. Special attention should be given to the amount of offset necessary for the felloe to provide proper body and brake-drum clearance. When welding the felloe band to the cut-down steel wheel, it

should be offset to the outside of the center line through the spokes to give sufficient body clearance.

Transportation-Committee Activities

THE STATUS of the work of the Transportation Committee, as stated at the meetings of the Subcommittee on Maintenance held May 17 in New York City, and that of the Subcommittee on Operation held June 27 at Saranac Inn, N. Y., is that each of these Subcommittees chose five subjects for study, assignments of the subjects were made to individual members of the Subcommittees and they have since been formulating procedure and accumulating data.

The subjects taken up by the Subcommittee on Maintenance and the assignments of these subjects to individuals by Subcommittee Chairman J. F. Winchester are as follows:

(1) Preventive Maintenance in Line with the Elimination of Mechanical Road-Delays, assigned to E. C. Wood

(2) Self-Maintenance as Compared with Service Station Maintenance, assigned to H. V. Middleworth

(3) Uniform Method of Cost Comparison, assigned to J. F. Winchester

(4) Depreciation of Motor-Vehicle Equipment, assigned to Eugene Power

(5) Crankcase-Oil Reclaiming, assigned to E. S. Pardoe.

The work on the formulation of procedure relative to the Training of Mechanics, which was prosecuted by T. L. Preble during 1928, is being continued by him; and F. C. Horner, Chairman of the Transportation Committee, will do whatever he thinks is necessary in line with the continuation of the work he began in 1928 in accumulating data on Manpower Requirements for Motor-Vehicles.

Operation Subcommittee Projects

The subjects decided upon by the Subcommittee on Operation at the meeting held June 27 and the assignments of these subjects by Subcommittee Chairman A. S. McArthur are as follows:

(1) Suitability of Equipment, assigned to W. J. Duffy

(2) Proper Speeds (Maximum; Rates of Acceleration and Deceleration; and Over-All Speed), assigned to E. D. Merrill

(3) Standardization of Body Builders' Dimensions, Such as Length Back of the Cab to the Center Line of the Rear Axle and to the End of the Frame, assigned to S. B. Shaw

(4) Ways and Means of Operating Scattered Fleets, assigned to E. W. Templin

(5) Personnel Training, including that for

service and for drivers, the latter being inclusive of driving ability and care of the vehicle. Under "Service," the subdivisions are for service and for field inspectors as maintained by the manufacturers and by the operators. This subject is as yet unassigned.

It is understood that each member of the Subcommittees to whom a subject has been assigned shall feel entirely free to contact with anyone whose ability enables him to be helpful in deciding just what the scope of the report should be and in developing material or data for the report. In this manner it is felt that each of these members who is accepting responsibility for the subject assigned him will have entire freedom to organize informally a group of helpers in case he may so desire.

It is hoped that each Subcommittee member to whom a subject has been assigned will have a progress report ready for presentation to the S.A.E. Transportation Committee at the meeting it will hold at Atlantic City, N. J., on either Oct. 2 or 3 during the Convention of the American Electric Railway Association. It is also hoped that final reports or further reports of progress will be available to the Transportation Committee at a meeting that may be called during the Transportation Meeting in Toronto, Canada, Nov. 12 to 15, or during the Annual Meeting of the Society in January, 1930.

Papers on Transportation

EXTENSION of motorcoach services over routes of 100 miles or more in length in all parts of the Country is shown by a map in the paper on Long-Distance Passenger Services, by R. E. Plimpton, printed in this issue, beginning on p. 285. Figures are given of the number of routes, the miles of highways over which the services are operated, running time, rates of fare charged and like data. Facilities and operating methods differentiating long-distance from suburban services are mentioned and the similarity to railroad practice pointed out.

In the paper by Lester D. Seymour on the Operating Experience of the National Air Transport, printed in this issue beginning on p. 217, the experiences of that organization in assembling equipment and personnel for the first route from Chicago to Dallas, Texas, are related, together with operating details; and similar information connected with the air-mail route between New York City and Chicago is presented.

A Significant Motorboat Conference

Representative Engineers Hold Stimulating Meeting in Detroit to Discuss Design and Construction Problems—Three Papers Presented

NO BUSINESS has a brighter future than the motorboat industry, for automobiles are working so well that they are crowding us into the water, declared C. F. Kettering, who presided at the motorboat engineering dinner and conference held in Detroit on the evening of Aug. 31, at the Whittier Hotel. The meeting, which was sponsored by the National Association of Engine & Boat Manufacturers, Inc., and held by the Society, was attended by many of the leading men in the industry, who were present because of the International Trophy Race held in Detroit that week.

As an indication that better days have arrived for boat builders, Mr. Kettering pointed to the fact that, while boat yards have in the past always been without work during the summer months, their records now show little falling off of business during the summer and at present every yard in the Country is busy almost to capacity. He pointed out that with this rapid rise in the popularity of motorboating the industry is finding it necessary and advantageous to follow the example of the automobile and aircraft manufacturers by increasing the safety factors and introducing standardization in design and construction.

Britons Taking to the Water

Arthur Bray, a member of the Marine Committee of the Society of Motor Manufacturers and Traders in London, said that, although road traffic congestion in England has not yet reached the point where the people are being forced into the water or the air for pleasure rides, Mr. Kettering's remark is applicable to a certain extent, and the increasing automobile traffic together with the advantages of the cheaper and easier navigation offered on water, as compared with air, are resulting in the marine field taking the lead, although standardization in the industry has only been started. America, he declared, was the first country to develop standardized boats, as she was first to develop standardization in motor-cars; and without question the American automobiles lead the world in quality as well as quantity. The long-stroke small-bore engine which is characteristic of the British cars, he explained, had been forced upon manufacturers by the horsepower tax, making the British cars unsuited to export trade and leaving the British colonies an open market for the United States. Thus far the Government licenses motorboats with-

out any tax, another item in their favor.

Harry Bower, a member of the Society of the German Automotive Industry, of Berlin, reported 2000 motor yachts are registered in Germany; but the builders have no standards, since each customer demands that his boat be different from that of his neighbor. Prior to the Great War, marine engines were built by the manufacturers of German motor-car engines, he stated, but for a number of years attention has been turned to the development and building of outboard engines which, while less powerful, sell at the same price as those built in America. The hulls, he stated, could be built much cheaper in Germany than in America and therefore a considerable export trade in boats without engines is being built up.

Industry Needs to Standardize

Jay W. Smith, president and general manager of the Chris Smith & Sons Boat Co., builders of the Chris Craft, stressed the point that the motorboat industry is now in the same stage that the automobile industry was 25 years ago. Entirely too much attention has been given to speed in boats, he declared; more attention should be given to safety, standardization and serviceability. It is not to the credit of the industry that all boat builders want to race their products, whereas no automobile manufacturer wants to race his automobiles. The point has now been reached, Mr. Smith declared, where boat manufacturers must come together and use the S.A.E. method for standardization in order to obtain safer and more serviceable boats.

The special problems revealed in the papers presented and discussed at the meeting were motorboat fire prevention, marine electrical equipment problems, and noise and vibration elimination.

Fire Prevention in Motorboats

In his paper on fire prevention, H. G. Kamrath, experimental engineer of the A C Spark Plug Co., showed the urgent need for greater safety from fire in motorboats because of the increasing number of unskilled owner-operators. He reviewed the causes of motorboat fires and discussed in particular the cause and cure of flames being blown out into the engine compartment during carbureter backfire. According to the reports at the Underwriters' Labora-

tories, an increase in the percentage of fires traced to this cause has been apparent. A review of automobile fire-loss reports showed that, out of 403 cases over a period of three years, 50 were directly traced to carbureter backfires. For the year 1927 and the latter part of 1928, approximately 10 per cent were traced to carbureter backfire. Of the 1928 fires, the percentage is 18. Mr. Kamrath described the approved type of flame arrester manufactured by the company with which he is connected, and quoted test results to prove its efficiency.

Better ventilation of engine rooms should be considered in reducing the fire hazard, stated A. E. Luders, president of the Luders Marine Construction Co. and chairman of the technical committee of the National Association of Engine & Boat Manufacturers, Inc. Mr. Smith agreed with Mr. Luders and emphasized the point that motorboat customers demand that bulkheads be provided to keep the gases and fumes from the engine out of the cabins, which aggravates the condition by confining the combustible fumes in a closed compartment with the engine, just the place where they should not be. He suggested that the down-draft carbureter might prove a real asset for use in motorboats from the standpoint of safety, since it would provide a place to catch the gasoline before it gets into the bilge.

Fire Underwriters Improved Automobiles

Entirely too many boats burn, declared Mr. Kettering, who recalled the same situation in the early history of the automobile. He said that the Fire Underwriters Laboratory had investigated the matter of automobile fires and collected statistical data as to the kind of installation of various items on the cars that burned, as well as regarding the construction of cars that did not burn. As a result of their findings, the underwriters issued certain specifications on which they would give reduced fire insurance rates. Automobile manufacturers at first resented this dictation from the fire underwriters on how to build their cars but, since the policy was based on statistics, the manufacturers were soon convinced that it would be wiser to heed the underwriters' demands. The standardization brought about by this method has resulted in the cars of today being notably free from fire hazard and they are insured

Cleveland Aeronautic Meeting Report

tive pressures are being increased, not decreased, and that the engine durability that is sought will be attained, together with other desirable features mentioned by Mr. Geisse. Mr. Geisse replied that he would not increase the mean effective pressure in his designs unless forced to do so by the conditions on which he wished to elicit discussion; also that possible improvement in economy is not confined to wide-open throttle operation.

L. F. Merrill, of the Continental Aircraft Co., agreed with Mr. Geisse that the cowling-design problem should be left to the engine maker. B. C. Bolton, of the Keystone Aircraft Corp., felt that it would be very difficult for the engine maker to produce a cowl that would fit the varying types of airplane.

H. K. Cummings, of the Bureau of Standards, expressed the opinion that cowling design should be handled jointly by the engine and the aircraft designer.

High-Temperature Liquid-Cooling

Gerhardt W. Frank, in his paper on High-Temperature Liquid-Cooling, stated the requirements of such cooling, giving a brief historical sketch of the development, including the investigation conducted by the Materiel Division at Wright Field. That investigation was divided into five parts, covering dynamometer tests of Curtis V-1578 and D-12 engines, endurance and flight tests of the D-12 engine, and a dynamometer test of a high-compression D-12 engine. It was indicated that the modern water-cooled aircraft engine, with minor changes, can be operated more efficiently at a cooling-liquid temperature of 300 deg. fahr., this entailing a sacrifice of approximately 3 per cent in power. The advantages of such operations are better fuel-economy; reduction of radiator size, amount of cooling liquid, engine installation weight and parasite resistance; and simple provision afforded for ample heating of inlet manifolds.

With normal compression-ratio, the D-12 engine has 10 per cent better fuel-economy when operated at 300 deg. fahr. cooling-liquid temperature than when operated at normal water-temperature. Increasing the compression ratio 30 per cent results in a further decrease of 20 per cent of normal fuel-consumption. The amount of radiator cooling-surface can be reduced 70 per cent, the volume of cooling liquid 30 per cent, and the engine installation weight 11 per cent. Mr. Frank said that the reduction in frontal area should reduce the radiator air-resistance from 15 to 4.5 per cent of the total air-resistance.

The ethylene-glycol used in this investigation is marketed as an automobile antifreeze preparation under the trade name of Prestone, by the Carbide & Carbon Chemicals Corp. Prestone, which contains approximately 3 per cent of water, has a boiling-point of 335 deg. fahr. and an initial freezing-point of approximately 0 deg. fahr. It is in the form of slush between 0 and —45 deg. fahr., and does not freeze solid until the latter temperature is reached.

Mr. Frank said that the higher cooling-fluid temperature had not caused trouble with the ordinary soft-soldered radiator joints. The same pump was used with the high-temperature fluid as with water.

Predicts Elimination of Radiator

As Mr. Geisse said in his discussion, Mr. Frank presented a splendid paper on a most interesting subject which is going to have a decided influence on future aviation-engine develop-

SPEAKERS AND CHAIRMAN AT THE POWERPLANT SESSION
J. H. Geisse (Left) Presented a Notable Paper on Gaging Engine Performance. Gerhardt W. Frank (Center) Made Public for the First Time Full Information on High-Temperature Liquid-Cooling of Engines. Capt. L. M. Woolson, Who Presided as Chairman

ment. The paper is the first release of comprehensive technical data on the subject by either the Army or the Navy.

Mr. Geisse predicted the elimination of the radiator as we now know it. He said that the feature of high-temperature liquid-cooling that impresses him as most important is the increase in heat dissipation from the jacket walls themselves. When the jacket walls are brought to a temperature of between 300 to 350 deg. fahr., they become excellent radiators. Mr. Geisse stated that it is doubtful whether the average surface-temperatures of the fins of an air-cooled cylinder, including the head, are in excess of this value. With equal mean air-velocities over the surface of the jacket of the high-temperature liquid-cooled engine and the fins of the direct air-cooled engine, it is only necessary to have an equivalent area to make the radiator unnecessary. As a matter of fact, the mean air-velocity can be made higher with the liquid-cooled engine in block form, and less area will be required. Mr. Geisse said that the useful limit of power in direct-air-cooled engines has been reached, but there is decided demand for units of greater power. With the radiator a part of the cylinder-bank, plumbing will be dispensed with. Possibly the cooling-system pump will be unnecessary.

S. D. Heron, of Wright Field, said that the "glycol" engine will stand much more abuse than will any air-cooled engine. Also, much is to be said for the uniformity of cooling of the former, not to mention increased fuel-economy.

To Increase Propeller Efficiency

Controllable-Pitch and Variable-Pitch Blades and Geared Propellers Discussed

FLYING at an altitude of 20,000 ft. at nearly double the attainable speed at sea level and with no greater fuel consumption can be foreseen as a development of the future in military aviation and air-mail transportation, according to Theodore P. Wright, chief engineer of the airplane division of the Curtiss Aeroplane & Motor Co. How this can be attained was pointed out in a joint paper prepared by Mr. Wright and W. R. Turnbull, consulting engineer of the Curtiss company, and read at the Propeller Session on Monday afternoon by Mr. Wright. Controllable-pitch propellers and supercharged engines will enable the pilot to utilize the full efficiency of the engine in taking off, in climbing, and then in level flight at great altitude.

The advantages of variable and controllable-pitch propellers were discussed also in a paper prepared and delivered by Frank W. Caldwell, chief engineer of the Standard Steel Propeller Co. Slides were shown of numerous sets of curves plotted from a series of tests run by the author of the paper and Prof. E. N. Fales showing the efficiency of the propeller at different angular settings of the blades at different horsepowers and over a range of static thrust. "From the standpoint of practical operation, we can gain by a lower pitch-setting, both in actual propeller efficiency for take-off and in increased engine horsepower due to increased revolutions," said Mr. Caldwell; "but to take full advantage of pitch adjustment, it must be under the control of the pilot in flight."

Gains to be realized by gearing propellers down from the engine were weighed against the disadvantages of installing reduction gearing in a third paper at the session, which was presented also by Mr. Wright, co-author with R. E. Johnson, also of the Curtiss Aeroplane & Motor Co. in charge of the aerodynamic laboratory. "At best the installation of reduction gearing is a compromise between the gains and losses involved," according to the authors, "and the amount of net gain depends largely upon the particular engine and airplane combination and upon its design and performance."

Three Chairmen Preside Successively

Three chairmen presided in quick succession at the meeting. Lieut. C. B. Harper, of the Bureau of Aeronautics of the Navy Department, who was scheduled to preside, was delayed at the Cleveland Airport, where, as he announced later, Col. Charles Lindbergh was making some propeller tests for the Navy. So Capt. E. S. Land, of the Guggenheim Fund for the Promotion of Aeronautics, was induced to start the session, although he had just arrived by airplane after a 450-mile flight and had not eaten since an early morning breakfast. After the presentation of Mr. Wright's first paper, Captain Land turned the meeting over to Lieutenant Harper, who had come in but could remain only a few minutes and quickly relinquished the chair to Major Leslie MacDill, of the Air Corps.

Advantages of Controllable Pitch

To remove the confusion that has arisen regarding just what is meant by adjustable, variable and controllable pitch, Mr. Wright and Mr. Turnbull, in their joint paper, defined fixed-pitch propellers as those having the blades and the hub integral and of the same material throughout; ground-adjustable propellers as those having the hub and blades of different materials and the blades clamped to the hub on the ground at an angle to give the assumed best or some desired performance results; and controllable-pitch propellers as those having the blades mounted in the hub so that they can be turned about their radial axes during flight and at the will of the pilot.

Superiority of the controllable-pitch propeller over the other types lies in the fact that the pilot can decrease the pitch of the blades when taking off and when climbing so as to take advantage of the higher engine-speed and power, and then, when leveling off for straight flight with the engine developing full horsepower, can increase the pitch of the blades. The advantage of the controllable-pitch propeller is most apparent during climb, when a decrease of only 2 or 3 deg. in blade pitch has been shown in tests to increase the rate of climb from 31 to 85 per cent.

The controllable-pitch propeller is of particular advantage on multi-engine airplanes because, if one engine fails the pitch of the propeller on the other engine or engines can be reduced so that the engine or engines can be run at their proper speed despite the reduced air-speed of the plane, and, further, the blades of the propeller on the dead engine can be feathered to reduce the parasite resistance to the minimum.

In the latter part of their paper the authors deal with the problem of design of this type of propeller, materials of construction, safety accessories and the history of development. This and the other two papers will appear shortly in the S.A.E. JOURNAL.

Mr. Caldwell, in his paper, analyzed static thrust and the frictional forces and twisting moments that have to be overcome in operating the controls of the propeller blades while in flight, and then showed slides of a design of a controllable-pitch metal propeller with its operating mechanism. In closing, he stated that the aerodynamic advantages of such propellers are becoming increasingly important as propeller-tip speeds and engine horsepower increase. With improved materials and design, he asserted, we should soon be in a position to meet the practical requirements of the problem.

Pitch Range and Control Means

In the discussion the range of pitch control and the means of control were first taken up. Lieut.-Commander C. H. Havill, of the Bureau of Aeronautics, said he believes that for the smaller craft a range in the head position of possibly 5 deg. and at the outside limit 10 deg. is wanted, and that development

probably will work out some type of automatic pitch-control that will give 3 to 5 deg. variation in the head position, and also some type of completely reversible propeller for very large craft which are hard to handle in high winds. The reversible type will not be much needed, as brakes have largely solved the stopping when landing. The Navy, he said, has seven automatic control propellers; one to give 3-deg. change in head position from take-off to top speed, and five to give 5-deg. change automatically. These are in the experimental stage. Owing to the increasing power of engines, he thinks power control, rather than manual control, of the blade-pitch is coming, but that automatic control will be the final answer. One of the Navy automatic-control propellers fitted to a Hornet engine has the blades set at 18 deg. when at rest on the ground. At an engine speed of 900 r.p.m., the angle drops to 15 deg. and remains there until an air speed of about 100 m.p.h. is attained, when the angle automatically increases to 18 deg. The hub weighs only 8 lb. more than the standard hub.

Control to Gain Fuel Economy

One specially striking point, remarked Edward P. Warner, is the gain in fuel economy that results at cruising speed from a very marked increase of propeller pitch. This has not been very generally appreciated by aeronautic engineers or aircraft operators. A theoretical investigation carried out by Major MacDill about 6 years ago indicated the necessity of having a rather elaborate automatic control if the con-

trol is to be automatic, as, contrary to common assumption, the economy tests have shown that more is required of a variable-pitch propeller than that it shall keep the engine revolutions constant for a given throttle setting. A great deal of scope exists, thinks Mr. Warner, for the exercise of ingenuity in developing a follow-up control that will enable the pilot to set an indicator for the blade angle he wants and have the blades take that angle quickly without his having to watch the indicator and exert any force on a control or move the control through any considerable distance. There should be no difficulty about securing a power drive on the propeller so that the pilot can have an indicator reading from 10 deg. astern to 40 deg. ahead, or 90 deg. for streamlining the blade when the engine stops, and that can be set with the turn of a knob to any point on the dial and the propeller will set itself in 3 or 4 sec.

Mr. Wright replied that it is true that the entirely automatic pitch-adjustment which maintains a constant engine-speed has certain decided limitations particularly in fuel economy when cruising. He thinks, however, that the Hele-Shaw device has some provision for allowing the pilot to pick out the engine speed he wants to obtain, and the adjustment to give that speed is automatically controlled and maintained.

Lieut.-Commander Havill mentioned that the Navy automatic pitch-control has a little attachment that governs the pitch by the air speed so that the pilot can cruise at full throttle. The pitch automatically increases during a

5-min. climb. However, this imposes heavy bearing pressures on the engine, and for this reason the adjustment was limited to 5 deg.

Effect of Gearing on Cooling

Commenting on the paper on the gearing of propellers, Chairman MacDill stated that sometimes the additional radiator capacity made necessary with water-cooled engines because of the decreased slip-stream velocity behind the slower-turning geared propeller has increased the weight of the airplane. However, he feels that many airplanes could be improved by the use of gearing and that, with the development of the supercharger, the necessity of gearing is becoming more and more important. He urged manufacturers who are contemplating very high-speed engines, that are likely to be used principally in airplanes in which gearing shows decided advantages, to bring out the engine with the gearing and have the tests made early on the gearing.

Harold Caminez questioned the statement in the paper that the gearing of engines of less than 400 hp. is not warranted by the net gain, and mentioned a 30-hp. two-cylinder air-cooled engine equipped with reduction gearing. He would not recommend gearing for insufficiently cooled engines or for air-cooled engines unless it is certain that they will cool adequately.

The two entirely distinct functions of gearing, pointed out Mr. Warner, are to make propeller speed safe and low enough to avoid noisiness and to increase efficiency.
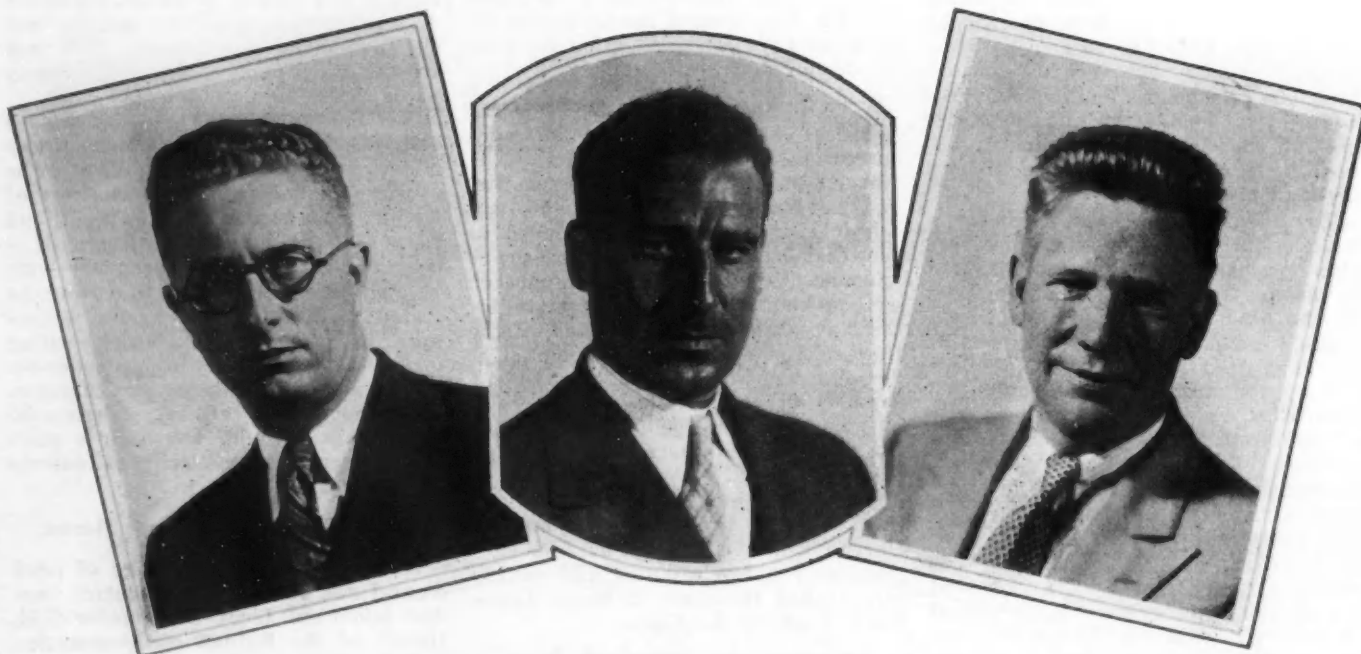
CHAIRMAN AND SPEAKERS AT THE PROPELLER SESSION
T. P. Wright (Left), Who Presented Papers on Controllable-Pitch Propellers and Gearing of Aircraft Propellers. Lieut. Carl B. Harper (Center), One of the Chairmen. Frank W. Caldwell, Who Gave a Paper on Variable-Pitch Propellers

Properties and Uses of Light Alloys

Their Corrosion Resistance and Applications in Engine Design—Motion Pictures of New Metal-Clad Airship

THE concluding session of the Aeronautic Meeting on Wednesday morning, Aug. 28, was devoted to papers and discussion on aluminum, magnesium and beryllium alloys for use in aircraft construction and to motion pictures of the new ZMC-2 all-metal airship built in Detroit for the Navy. Carl B. Fritsche, who presided, remarked in opening the session that the whole objective of the aircraft industry seems to be to make aircraft stronger and as light as possible and that the very definite trend toward all-metal construction should make the excellent papers of interest to all.

E. H. Dix, of the Aluminum Co. of America, who wrote and presented the first paper, Service Characteristics of Light Alloys, is said to be responsible, more than anyone else, for having conceived the idea of producing Alclad metal. The function of the pure aluminum with which the duralumin core is coated by rolling the sheet under very heavy pressure to produce a physical union is to protect the core metal against corrosion through the electronegative characteristic of the pure aluminum. A large part of the discussion on Mr. Dix's paper and on the paper by G. D. Welty, of the same company, on the application of light alloys to aircraft-engine design, related to corrosion and its prevention.

Aluminum and Magnesium Alloys

In the first half of his paper, Mr. Dix dealt with the various aluminum alloying elements, the physical properties of magnesium-base alloys, the stability of magnesium and its alloys under most atmospheric conditions, the heat-treatment of light alloys, natural aging at room temperature and artificial aging at elevated temperatures, and the gradual increase in tensile strength after quenching. The latter half of the paper dealt with types of corrosion, its relative importance in service, and means of protecting the metals against corrosion.

Corrosion may occur, explained Mr. Dix, in three ways: first, by a uniform solution of the surface of the metal, which is not to be greatly feared, as the extent of the damage is readily determined by visual examination; second, by pitting, or localized corrosion, which produces a notch effect that decreases the ductility as well as the tensile strength and is likely to cause sudden failure without the usual amount of plastic deformation; and, third, by intergranular corrosion along the grain boundaries in certain of the heat-treatable aluminum alloys, which causes a decrease in tensile strength with a marked reduction in elongation. A great deal has been learned in the last five years about this third type of attack, which may produce considerable deterioration with only a relatively small amount of visible corrosion. In experiments at the Naval Aircraft Factory, H. C. Knerr determined that the rate of quenching an aluminum alloy containing copper and magnesium silicide has a marked influence on the rate of intergranular corrosion, and showed that quenching in cold water greatly reduces this susceptibility.

After describing the method of producing Alclad, Mr. Dix stated that the high-purity aluminum surface not only protects the alloy of the core by acting as a covering but also exerts an electrolytic protection over exposed areas, as at the sheared edges of sheet or in abraded areas. This is due to a difference in potential that has been found in a salt-water solution to amount to 0.15 to 0.20 per cent of a volt. In one experiment it was found that an area of exposed alloy 1 in. in diameter was protected by the presence of the surrounding aluminum during both alternate and constant immersion in a salt-water solution containing a small quantity of hydrogen peroxide. This electrolytic protection is of importance in aircraft structures in which rivets of uncoated alloy are used. It also indicates the importance of avoiding the putting of electropositive metals, such as copper and brass, into contact with aluminum, which greatly accelerates the corrosion of the aluminum. For the same reason, nickel-plating is unsatisfactory as a protective coating for aluminum.

Very satisfactory results in commercial use have been obtained from painting aluminum alloys with paints and varnishes, according to Mr. Dix. Thorough cleaning before application of the paint is important, and it is now generally believed that the best method is to remove the grease with a mild chemical cleaner that does not attack the metal. Artificially formed oxide films with a liberal coat of grease over them are also advocated, and a number of experiments have indicated that the chief advantage of these films lies in their use as a base for paints and varnishes. Bituminous paints with or without aluminum bronze powder also give excellent protection against severe conditions, such as those encountered by pontoons.

In written discussion submitted by L. C. Milburn, chief engineer of the Glenn L. Martin Co., questions were propounded as to the comparative values of the salt-spray and the alternate immersion tests, and regarding the corrosive effects of nitrate remaining on quenched material after washing. Mr. Milburn stated in conclusion, with regard to painting all parts before assembly, that this is not only advisable but is absolutely necessary. His company has had excellent success with bituminous paint mixed with aluminum powder, as this type of paint is nonhydroscopic.

Electric-Furnace Heat-Treatment Preferable

Replying to the questions, Mr. Dix said that the Aluminum Co. of America uses both the alternate immersion and the salt-spray tests, and finds that using a 20-per cent salt solution for the spray gives the same loss in mechanical properties in about three or four months as is obtained in about 48 hr. in the alternate immersion test, in which hydrogen peroxide is added to the salt solution to accelerate the intergranular corrosion of the strong aluminum alloys. Five or six years' experience shows that the two kinds of test check up very well; the company has never had a case in which one alloy that was shown by one test to be superior was not also shown by the other test to be better. There is no question, said Mr. Dix, that nitrate from the heat-treating bath remaining on the sheet has a highly undesirable effect. Present practice is to quench in cold water, then rinse the sheet in boiling water to remove the nitrate. He expressed belief that the ultimate heat-treatment for aluminum will be

PROPELLER BLADE AND CAST CRANKCASE AND PISTON OF LIGHT ALLOYS SHOWN BY MR. WELTY
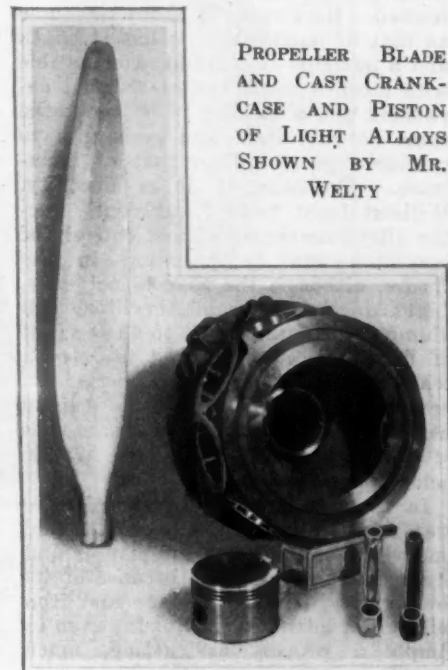
JUAN DE LA CIERVA IN THE AUTOGYRO

Miss Thea Rasche (Left), Leading German Aviatrix, and Mrs. Louise Thaden (Right), Winner of Women's Airplane Derby from Los Angeles to Cleveland

by the electric furnace, when the same uniformity can be obtained with large furnaces as with the nitrate bath.

Practical Possibilities of Beryllium

Two major difficulties stand in the way of making practical application of beryllium alloys at present. One is lack of ductility of the metal and the other is its high cost. C. B. Sawyer, of the Brush Laboratories Co., who contributed written discussion on the subject, stated that beryllium has a peculiar combination of properties that justifies most serious engineering attention. Its density is about the same as that of magnesium, it has strength and a modulus of elasticity comparable with steel, a coefficient of thermal expansion and a melting point about the same as cast iron, and resistance to corrosion greater than that of aluminum. However, it lacks ductility. Without doubt, he said, sufficiently ductile alloys consisting almost entirely of beryllium can be prepared in the future, although the task is not easy. Light ductile alloys of beryllium and aluminum, containing up to 60 per cent of beryllium, are reported to have a tensile strength of 80,000 lb. per sq. in. or even higher, and have a density nearer that of magnesium than that of aluminum and should have a wide field of application.

In the unalloyed and rather brittle state, beryllium probably could find immediate employment for pistons and other castings in which, because of its low density, it could replace cast iron with great advantage. But for even so simple a process as casting, much

knowledge concerning methods of handling beryllium is needed.

Present high cost of the metal stands in the way of its commercial use, but Dr. Sawyer stated that, when the development period has been passed and a fairly large-scale production is established, the combined cost for ore and its electrolysis should bring the production cost of the metal to between $1.40 and $2.70 per lb., which will place the metal well within practical limits of use. ·

Uses of Light Alloys in Engines

Mr. Welty gave an oral summary of his paper on Modern Light Alloys and Their Application to Aircraft Engine Design and exhibited a cast alloy radial-engine crankcase, a light-alloy piston, and an alloy propeller blade. Wrought and heat-treated aluminum alloys, commonly termed "strong alloys," constitute three-quarters of the total volume and about one-half the total weight of modern aircraft-engines, he said. For certain applications the thermal conductivity of the alloys is of equal or greater importance than the lightness or the strength. Tables of the composition and physical and mechanical properties of various aluminum and magnesium wrought and casting alloys were given and the various uses of them explained. Referring to the more recently developed alloys, Mr. Welty said that modern heat-treated casting alloys have already displaced No. 12 aluminum alloy for crankcases, gearcases, housings and oil-pans and numerous smaller parts. Heat-treated alloy No. 195, for example, possesses

high relative toughness, which prevents the occurrence of high localized stresses where large engine castings are bolted together. Another advantage is its lower density, which is 2.77, as compared with 2.86 for No. 12. In an engine carrying 200 lb. of castings of this character, this seemingly small difference would amount to a weight saving of more than 5 lb., which, at the often quoted figure of $20 per lb., would exceed $100 per engine. The field of No. 195 heat-treated alloy includes all structural castings that require maximum strength and reliability combined with minimum weight.

Among the special-purpose alloys, Mr. Welty mentioned Y alloy, designated No. 142, and No. 122 aluminum alloy. Both are used extensively in this Country as piston and cylinder-head materials for radial air-cooled engines. The advantage of Y alloy over No. 122 lies in maintenance of strength at elevated temperatures, but its yield-point is actually inferior to that of No. 122 at a temperature of 600 deg. Fahr. and higher. But Y alloy has a specific gravity of 2.79 as against 2.90 for No. 122. A 500-hp. radial engine will normally carry about 200 lb. of pistons and cylinder-heads which, if made of Y alloy, will weigh 7 or 8 lb. less than if made of No. 122. From the standpoint of satisfaction in service, the two materials are virtually the same.

An aluminum piston-alloy that has been under development for a number of years and is beginning to find commercial application is designated No. 132. Its chief advantages lie is a substantially lower coefficient of expansion than that of aluminum and an almost identical specific gravity, 2.7. Pistons made of it can be fitted with about 20 per cent less clearance than is required for pistons of either Y alloy or No. 122, and the lower specific gravity reduces reciprocating weight and makes possible a reduction of crankshaft weight. With the cemented tungsten-carbide tools now available, it can be machined even more readily than can the standard piston-alloys with standard tools. The thermal conductivity seems to be about equivalent to that of Y alloy or No. 122. Alloys of this type are much more difficult to handle in sand molds than in permanent molds, however, and their application for cylinder-head castings must await the development of proper foundry technique.

Magnesium Alloys Becoming Available

Through intensive research extending over the last 8 or 10 years, magnesium alloys have been developed and processes perfected, said Mr. Welty, by means of which magnesium products can now be produced that are far harder and more resistant to corrosion than those of the earlier period. The

results of these efforts are becoming available and it is safe to predict that magnesium-base alloys will be applied extensively to aircraft construction. To the engine designer, magnesium has always possessed alluring possibilities because its specific gravity is only 60 per cent of that of aluminum and the strength of magnesium-alloy is equal to the best of the sand-cast and heat-treated aluminum compositions. The first extensive use of magnesium will come in sand castings, because the foundry practice for producing such castings is better developed than is the art of producing magnesium forgings. Machinability of magnesium castings is one of the greatest assets of the material. In resistance to fatigue magnesium castings are fully equal to aluminum-alloy castings, asserted Mr. Welty, but it is recommended that thorough tests be carried out before adopting magnesium-alloys for major structural castings such as crankcases or thrust bearings as, compared with aluminum, its background in engineering experience is relatively small and a somewhat conservative attitude is likely to be attended with the best results.

Even at present prices, a volume-for-volume substitution of magnesium for aluminum involves a cost increase of only 25 to 60 per cent. As a substitute for heat-treated aluminum alloys in structural castings for strength and lightness, the present magnesium alloys are likely to go far, according to Mr. Welty, but as a substitute for Y alloy or No. 122 in pistons and cylinder-heads, their future is more dubious, as they do not compare with either of these aluminum alloys in hardness or bearing qualities and their thermal conductivity is only half as good.

Welding Tubular Fuselages

Practical information and advice on the oxy-acetylene welding of tubular steel fuselage structures were given in the final paper of the session by Richard M. Mock, aeronautical engineer of the Bellanca Aircraft Corp. An interesting phase of the work is the method used by the Bellanca corporation to solve the problem of warpage during welding. The tubes are first cut to exact length and prepared for assembling in the fuselage jig, which weighs 5 tons and takes the complete fuselage structure. The jig is of angle-irons having the same shape as the fuselage so that the tubes when clamped in the angles, which are open outward, are located correctly for the side-truss frames. Both side panels are welded at once, and all outside welding is completed in the jig, which is mounted on bearings so that it can be turned over easily for welding on the bottom. Tack-welds are avoided, as warpage would tend to pull the tacks or cause some damage if the tack-welds were too strong to give way. About 75 per cent of the welding is completed in this jig, after which the side trusses are taken out. The members have practically no tendency to cling to the angles and no tendency to spring, and the panels check for length to within ⅛ in. Three pairs of side panels can be produced in this jig in an 8-hr. day, employing four welders and two set-up men.

A fuselage assembly-jig of much lighter construction than the side-panel jig supports two side-frames from the outside. Cross members are put in it and welded in place, all except about 5 per cent of the welds being completed in this jig. Upon removal, the fuselage is true for length within ⅛ in. and the hinges are never more than 1/32 in. out of position, asserted Mr. Mock.

Motion Pictures of ZMC-2 Explained

Three reels of motion pictures of the construction and flight of the new ZMC-2 airship, flown for the first time in August, provided a fitting conclusion of the Cleveland Aeronautic Meet-

CHAIRMAN AND SPEAKERS AT THE LIGHT-ALLOYS SESSION
Carl B. Fritsche (Upper Left), Chairman. E. H. Dix, Jr. (Upper Right), Who Told of the Service Characteristics of Aluminum and Magnesium Alloys. G. D. Welty (Lower Left), Who Defined the Application of Modern Alloys to Aircraft-Engine Design. R. M. Mock (Lower Right) Described Tubular Fuselage Welding Methods

ing. As Chairman Fritsche said, they constituted probably the most expensive scenario that will ever be presented at an S.A.E. meeting, representing a cost of at least $750,000. For assistance given in connection with the ship, tributes were paid by the Chairman to the Bureau of Aeronautics, Rear Admiral Moffett, Edward P. Warner, then Assistant Secretary of the Navy; Captain Land, then assistant chief of the Bureau; Garland Fulton, in charge of lighter-than-air craft; and Dr. C. B. Burgess and L. B. Tuckerman, of the Bureau of Standards.

As the pictures showed, the two halves of the ship were built separately in a vertical position, so that most of the work could be done on the ground. The circumferential strips of duralumin were sewed together with tiny metal rivets by a specially built machine. When completed, the halves were turned horizontally and jointed. Then the envelope, which contains no gas bags, was inflated with carbon dioxide from the bottom to force out the air. Helium was then introduced at the top while the carbon dioxide was pumped out from the bottom. When 40 per cent of helium was revealed in the gas analysis, the gases were run through a caustic-soda scrubber, which effectively removed the carbon dioxide. This method cost about $2,000, whereas it would have cost about $70,000 to install a plant to freeze out the air.

Credit for the conception, design, construction and flying of the ship was given by Chairman Fritsche to Ralph Upson and his associates; E. J. Hill, who developed the ingenious riveting machine; Arthur Slosser, shop superintendent; and Captain Kepner. When introduced and called upon to make a few remarks, Captain Kepner said that, in his opinion as an operator, the fact that the ship made five flights in its first week of flying was a record for any airship, even one of standard design. He has flown every airship that exists in the world today except the Graf Zeppelin, he said, and does not know of any that has gone out in its first week of flight without having something changed. "We have finished enough tests," he said, "to be able to say conclusively than it is an airship, and we are going to find out just how much better it is than other ships."

in a fog a concentrated high-power beam or a great flood of diffused light is more conspicuous. Also, there is a question whether a steady or an intermittent light is discernible from a greater distance in fog. On European landing-fields colored boundary-lights are used; whereas in this Country these lights are mostly white, with some chance for their being confused with parallel street-lights. Possibly flashing boundary-lights would be preferable. A great deal also remains to be learned regarding the locating and mounting of flood-lights.

Size and Mounting of Instruments

In connection with the recently adopted S.A.E. Recommended Practice for instrument dimensions and dimensions of mounting cases, a communication was received from Chief Engineer Ileman, of the Consolidated Instrument Co. of America, Inc., advocating that all pointers be placed so that they will be in horizontal position when the aircraft is in normal operation, the instruments being arranged so that all pointers will move upward when the aircraft is climbing, and downward when the nose of the machine is pointed downward. Wesley L. Smith, of the National Air Transport, Inc., said that in his opinion, in view of the instrument problem, the stage of possible standardization of instrument arrangement has not been reached; that, whereas the instrument men have started to make the dials smaller, they should be larger. John D. Peace, Jr., of the Pioneer Instrument Co., agreed that it is too early to standardize instrument arrangement. Major Leslie MacDill said that the number of instruments will continue to increase, and that, in mounting, the arrangement should be such that the pointers of a large number of instruments will lie in the same direction normally, preferably horizontally.

Wheels, Rims and Tires

B. J. Lemon, Chairman of the Airplane Tires, Wheels and Rims Subdivision, submitted a recommendation for one change in the Recommended Practices and Standards recently adopted by the Society and appearing on pp. 17 to 25 of the S.A.E. HANDBOOK Supplement issued last month. This change relates to the depth of the well of the 10-in. and 12-in. drop-center airplane wheel rims, it having been found that it is somewhat difficult to mount 10-in. and 12-in. tires on the drop-center rims of the present well depth. It was recommended that the well depth of the 10 and 12-in. rims be increased 1/16 in. The members of the Aircraft Division present formally accepted this recommendation.

Mr. Lemon referred to the need for international standardization of wheels, rims, hubs and axles. John R. Cautley

Aircraft-Lighting Report Presented

Standards Session Adopts Wheel-Rim Recommendation and

Discusses Instruments, Propeller Shaft-Ends

and Other Subjects

THE STANDARDS Session held on Monday morning was of unusual interest. E. P. Warner, Chairman of the Aircraft Division, presided. Speaking of the steady increase in aeronautic standardization work, he said that the number of standards would be added to as rapidly as the aeronautic industry, through its leading technical men and controlling officials, assimilate results to date and express specifically a desire for extension of the work along definite lines. Those who are building, distributing and using aircraft are the natural guides for the work.

Lighting

Standardization in connection with aircraft lighting is now apparenlty possible. The Lighting Subdivision of the Aircraft Division has been doing considerable cooperative research work, this being possible through generous assistance from manufacturers and operators in the effort to secure the best form of lighting. W. M. Johnson reported on the work of the Subdivision. His report is printed in the Aeronautic Engineering department in this issue of THE JOURNAL, p. 304.

F. G. Diffen suggested possibilities of standardization of features of airport lighting. The first installation of a signal system to which he referred is being made at Grosse Isle, near Detroit. In this, runways are lighted automatically according to wind direction.

L. C. Porter, who has been very active in the illumination research which is vital to the aeronautic industry, urged that the ridiculous situations which have developed in other fields be avoided. In France certain lighthouse lights mean exactly the reverse of what they mean in the United States. Mr. Porter told of the current studies of the Committee on Aviation Lighting of the Illuminating Engineering Society. Much is to be learned about lighting and lighting equipment. Fundamental principles must be outlined so that ways and means can be developed. Colors must be standardized for signals, beacons, runway lights and other equipment. Advantage can be taken of the color standardization of the railroads. At a certain point an extended flash-period increases the visibleness of a beacon, but the extent to which the flash period can be increased at the cost of beam candlepower is not known. There are no definite data on whether

said that in England 72 sizes of air-plane wheel and 29 sizes of airplane tire are being made, in addition to specials. All of the tires, as well as most of the axles, are dimensioned on a millimetric basis. He did not feel that the need for international standards could be met at an early date. Chairman Warner said that at the present time the lack of standardization is a serious matter for Canadian aircraft operators in fitting American wheels on British aircraft, and vice versa. In England the clincher-type rim is still being used.

Bolts and Nuts

J. M. Gwinn, Jr., of the Consolidated Aircraft Corp., in a written communication, brought up the subjects of tie-rods and cable terminals and of bolt and nut standards. He said that the standard tie-rod and cable terminals, when used with S.A.E. 1025 carbon-steel fittings, work at very high bearing-pressure in the pin-hole, resulting in elongation of the hole. With regard to the AN bolt-standards, Mr. Gwinn said that in his opinion these were formulated to meet the needs of the Army and Navy services rather than the airplane makers. He said, for example, that

"the castle-nut slot-depth, bolt thread-length and cotter-pin-hole location are designed to permit ⅛ in. variation in the bolt grip. Note, however, that the use of any grip greater than the minimum puts threads in bearing, which is prohibited by the Army and Navy, and should not be used on any fitting taking symmetrical loads. Therefore, pack washers must be used in many cases to prevent threads in bearing and the ⅛-in. adjustment on the bolt is of little value. From a manufacturer's standpoint 1/16-in. intervals are desired, as it is cheaper to carry in stock bolts of correct lengths for the job and have a simpler assembly problem than it is to have to use bolts in many

W. M. Johnson
Chairman of the Lighting Subdivision of the Aircraft Division

cases 3/32 in. too long in the unthreaded portion of the shank. Another criticism of the bolt standard is that the diameter tolerances are such that a bolt to the top tolerance will not go in a reamed hole, whereas a bolt to the bottom tolerance is so sloppy in a reamed hole that many times it cannot be used satisfactorily in control systems, pin-jointed engine mounts and the like."

B. C. Bolton, of the Keystone Aircraft Corp., brought up the matters of aluminum-alloy lugs and of possibly formulating terminal standards to permit proper use of them. C. V. Johnson, of Wright Field, said that in his experience there are few, if any, cases of elongation of holes when lugs are used in tension, but that under conditions of reversal of load there is usually con-

siderable elongation. John F. Hardecker, of the Naval Aircraft Factory, reported that with aluminum there had been some difficulty with elongation of holes, but that no trouble had been encountered in the use of 1025 steel. With regard to Mr. Gwinn's comments on the AN bolt-standard, Mr. Hardecker expressed the opinion that if the industry wants 1/16-in. variation in length of bolt, the Army and Navy would have no serious objection.

Propeller-Hubs and Shaft-Ends

Gustaf Carvelli, of the Curtiss Aeroplane & Motor Co., brought up the question of the addition of a larger size of shaft-end than is provided in the present standards, to be known as No. 50. This hub will find use particularly on large engines of the geared type.
F. W. Caldwell, of the Standard Steel Propeller Co., said that it is important that a No. 50 shaft-end standard be developed. He spoke also of the need for a standard shaft-end smaller than the No. 1, which is of taper construction. He said that at the present time about 30 different shaft-ends are being made in these small sizes, which makes a difficult production situation for the propeller makers. This matter was referred to the Aircraft-Engine Division, which already has in hand the matter of the No. 50 shaft-end.

Other Items of Work Suggested

Chairman Warner, in speaking of the aircraft standardization work in general, said that various items had been suggested, namely: aircraft cabin-hardware, including hinges and door latches, robe-rail attachments and window regulators; also gears and shock-absorbing elements; dimensions of streamline, as well as round and square steel and duralumin tubing.

Significant Motorboat Engineering Conference

at remarkably low rates. This is certainly not yet true of motorboats.

Engine Insulation To Prevent Vibration

Objectionable engine vibrations in motorboats will soon be a thing of the past, was the prediction made by I. W. Robertson, of the Firestone Tire & Rubber Co., in his paper entitled, Rubber Insulation for Motorboat Engines. The author stated that no great amount of work has been done or experience accumulated regarding the insulation of motorboat engines. The recommendations and tentative designs he offered were based on facts acquired from the automotive field, in which the use of

rubber for insulation purposes and vibration dampening has become almost universally recognized.

Mr. Kettering called attention to the fact that 14 times as much energy can be stored in rubber as in the same weight of steel. He said the light weight of rubber produces a very small inertia effect and makes it a most successful insulator against vibration. However, he advised designers that the wide range of frequencies to be dealt with might result in many unsuccessful trials before all the desired advantages are obtained. Mr. Smith agreed that the use of rubber insulation is a promising field but expressed the opinion that the most serious trouble

does not arise from engine vibrations. While vibrations of the engine make severe service for gasoline tanks, gasoline lines and other parts connected directly with the engine, he contended that the most serious trouble arises from the fact that boats, as compared with land vehicles, have no springs and the shock from hard contact with "solid" water is quite as severe as it would be on an unsprung automobile. With reference to the use of rubber bearings in the propeller-shaft, which Mr. Robertson stated had been successfully developed by the Goodrich Rubber Co., Mr. Smith said that his company is still experimenting, with the

Edward T. Jones

BY THE death of Edward T. Jones on Aug. 30 the Society lost one of its outstanding aeronautic members. This occurred at his home in Ridgewood, N. J., following an illness of three months with typhoid fever. At the time of his death Mr. Jones was chief powerplant engineer for the Wright Aeronautical Corp., of Paterson, N. J., a position that he had held for more than three years. He was born at Saratoga Springs, N. Y., Oct. 20, 1888, and obtained his technical education at Cornell University, from which he was graduated in 1911 with the degree of Mechanical Engineer.

After graduation, Mr. Jones took the apprentice course with the Westinghouse Electric & Mfg. Co., at East Pittsburgh, and the following year accepted a position as instructor in engineering thermodynamics at his alma mater. In 1915 he became experimental engineer with the H. H. Franklin Mfg. Co., of Syracuse, N. Y., leaving there the following year to act as inspector of airplanes and aeronautic engines for the Signal Corps. In 1917 Mr. Jones was commissioned as First Lieutenant in the Air Service and, after being engaged in aircraft production work for 18 months, was transferred to the powerplant section of the Engineering Division with the title of mechanical engineer, becoming chief of that section in 1922. On Dec. 15, 1925, he became associated with the Wright Aeronautical Corp. as chief of the engine-design department, and in 1926 was made chief powerplant engineer, the position he held at the time of his death.

Mr. Jones was a very active member of the Society following his election to Member grade on March 15, 1926, and joined the Metropolitan Section at that time. Immediately after his election he was made a member of the Aeronautic Division of the Standards Committee and was reappointed in 1927 and 1928. When that Division was broken up into the Aircraft and Aircraft-Engine Divisions at the beginning of this year, Mr. Jones became a member of the latter. He had also been a member of the Aeronautical Safety Code Sectional Committee since 1926. At the 1927 Annual Meeting he was elected Second Vice-President representing aviation engineering and was a member of the Meetings Committee for that year. Mr. Jones' activities this year included, in addition to those already mentioned, membership on the Aeronautic Committee, the Fuels Subcommittee of the Research Committee, and the Joint Army and Navy Aeronautic Conference. At the 1926 Aeronautic Meeting of the Society he presented a paper dealing with the Development of the Wright Whirlwind Type J-5 Aircraft Engine.

In appointing the personnel of Professional Activities Committees under the Society reorganization plan, the Council placed Mr. Jones on the Aircraft-Engine Committee shortly prior to his death.

Warren Packard

A HIGHLY successful engineering and business career in the automobile and aeronautic industries was terminated at the age of 37 years when a small seaplane in which they were riding fell in an inlet of the Detroit River on Aug. 26, resulting in the death of Warren Packard and the serious injury of Talbot Barnhard.

Warren Packard was the son of W. D. Packard, one of the founders of the Packard Motor Car Co., and was born at Warren, Ohio, in October, 1892. His technical education was acquired at Cornell University, from which he was graduated with the degree of Mechanical Engineer in 1914.

As private secretary to his father from 1914 to 1917, Mr. Packard had complete charge of all business affairs as regards his father's holdings in the Packard Motor Car Co. During 1917 he was assistant purchasing agent for the Curtiss Aeroplane Co. and assisted in the development of the Curtiss K-12 aviation engine. The following year he took the student training course at the Massachusetts Institute of Technology as inspector of aeronautic engineering materials for the Navy; and during the remainder of 1918 and part of 1919, prior to the armistice, he was attached as ensign to the engineering division of the Naval Flying Corps as inspector, having supervision of inspection of materials at the Curtiss Aeroplane Co. Later in 1919 he served as representative of the Bureau of Steam Engineering for aeronautics at the Brooklyn Navy Yard and the Naval Aircraft Storehouse, inspecting all Navy aviation material shipped overseas.

Upon the conclusion of the World War, Mr. Packard was associated with C. A. Neracher, C. E. F. Ahlm and Mr. Fritzsche in the development of the Neuelectric automobile transmission and later founded and became president of the Packard Engineering Co., of Cleveland, designing and marketing the Lovejoy hydraulic shock-absorbers and other automobile accessories.

Mr. Packard was admitted to the Society as Associate Member in May, 1919, and in September, 1921, was transferred to Member grade.

Dr. Edward B. Craft

A VICTIM of the intensive pace of modern business, Edward B. Craft, executive vice-president of Bell Telephone Laboratories, Inc., died at his home in Hackensack, N. J., on Aug. 20, following several months' illness due to high blood-pressure.

Dr. Craft was prominent throughout the engineering world because of his unusual accomplishments in the field of development. Born at Cortland, Ohio, on Sept. 12, 1881, he attended public and high schools in Warren, Ohio. After serving as superintendent of the lamp department of the Warren Electrical & Specialty Co., he went to Chicago in 1902 to enter the employment of the Western Electric Co. There he quickly demonstrated his talent for original work, and was soon put in charge of development work. His first invention, an indicating device for fuses protecting telephone equipment from electrical disturbances, remained in use in the telephone system for 23 years.

When development and research work of the telephone system was consolidated, in 1907, under the direction of Theodore N. Vail, Dr. Craft was transferred to New York City as development engineer in charge of telephone apparatus design for the Western Electric Co., and in 1917 was promoted to assistant chief engineer. Some of his most important work during this period was in connection with developing the dial telephone system.

Upon the entrance of the United States into the World War, Dr. Craft became a captain in the Signal Corps and in December, 1917, was promoted to the rank of major. He acted as technical adviser to the United States Navy, with headquarters in London, from June to October, 1918, returning to his normal work after the cessation of hostilities. He became chief engineer of the Western Electric Co. in 1922 and executive vice-president of the Bell Telephone Laboratories, Inc., in 1925.

Dr. Craft was elected a Member of the Society in September, 1923. He also was vice-chairman of the Division of Engineering and Industrial Research of the National Research Council, Chairman of the Board of Engineering Societies Library, a Fellow of the American Institute of Electrical Engineers and one of its managers from 1920 to 1924, a fellow of the Institute of Radio Engineers, a member of the council of the American Institute of Weights and Measures, and representative of the Bell System in the Aeronautical Chamber of Commerce. He was also member of the Metropolitan Section of the Society.

Personal Notes of the Members

Rickenbacker Joins Fokker Aircraft

Edward V. Rickenbacker, a man of singular achievement and a well-known figure in automotive circles, has been made vice-president and director of sales for the Fokker Aircraft Corp., located in New York City. To accept this position, Mr. Rickenbacker resigned the post of assistant general sales manager of the Cadillac Motor Car Co.

Mr. Rickenbacker became active in engineering matters at an early age, entering the engineering department of the Frayer-Miller Co. in 1905. Two years later he formed a connection with the Columbus Buggy Co. which was to last until the advent of the World War. He went overseas in 1917 and was assigned to the duties of chauffeur for General Pershing. Later he was transferred to the Aviation Division and served with the 94th Aero Squadron, subsequently being made a Commander. His distinguished service with the Squadron earned him the title of American Ace of Aces. In 1919 a book of his authorship appeared, bearing the title, Fighting the Flying Circus. In 1921 he assumed the position of vice-president and director of sales of the Rickenbacker Motor Co., but severed this connection five years later to become syndicate manager of the Detroit Aircraft Engine Works Syndicate, a firm engaged in developing five-cylinder air-cooled aircraft engines. In 1928 he joined the Cadillac Motor Car Co.

Mr. Rickenbacker became a Member of the Society and of the Detroit Section in 1928.

Lane's New Post

Kenneth M. Lane has resigned as chief plane engineer for the Wright Aeronautical Corp., of Paterson, N. J., to take up the duties appertaining to his recent appointment as chief of the engineering section of the Aeronautics Branch of the Department of Commerce, in the City of Washington.

Mr. Lane's activities as an aeronautical engineer have been noteworthy. In 1917, subsequent to receiving the degree of bachelor of science from the Massachusetts Institute of Technology, he was appointed aeronautical engineer in the engineering division of the Air Service at McCook Field, Dayton, where he assumed charge of the static testing of airplanes and the development of static-test methods. In 1921 he engaged in structural analysis and design for the Dayton Wright Co., and continued in this work until 1923, when he joined the Wright Aeronautical Corp.

In 1921 Mr. Lane was elected to Junior membership in the Society and in 1926 was advanced to Member grade. He has shown a keen interest in the work of the Society and has contributed valuable support to the work of the Aircraft Division of the Standards Committee, of which he is a member this year. He has been a member of the Metropolitan Section since 1927.

Chatfield Leaves M. I. T. Faculty

Charles H. Chatfield has resigned the associate professorship of aeronautics which he held at the Massachusetts Institute of Technology to become aeronautical engineer of the Pratt &
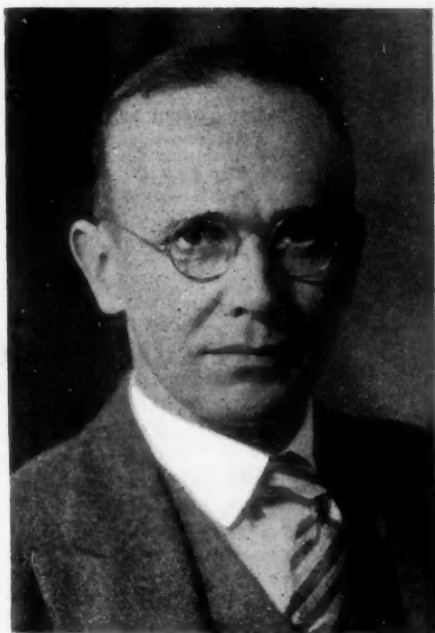
CHARLES H. CHATFIELD

Whitney Aircraft Co., of Hartford, Conn.

Mr. Chatfield acquired his technical education at the Massachusetts Institute of Technology, receiving there the degrees of bachelor of science and master of science. In 1917 he enlisted in the United States Naval Reserve Force and was assigned to duties in connection with the inspection of airplanes at various factories. In 1918 he took a special Government course in aeronautical engineering at the Massachusetts Institute of Technology, and during the two succeeding years was engaged in airplane structural design and stress analysis at the Bureau of Construction and Repair and at the Bureau of Aeronautics, in the City of Washington. In 1921 he went with the Wright Aeronautical Corp., at Paterson, N. J., as assistant plane engineer, and was made chief airplane engineer in 1925. The following year he was appointed to an associate professorship at M.I.T.

Mr. Chatfield's membership in the Society began in 1924, and he has been a member of the New England Section since 1927. Owing to his recent change in affiliation, his Section membership will be transferred to Metropolitan. He presented a paper at the 1927 Aeronautic Meeting of the Society on the subject of Monoplane or Biplane, which was published, together with discussion, in the S.A.E. Journal for January, 1928.

White Now Editor of Motor Boat

In accepting the editorship of Motor Boat, Gerald T. White, formerly chief engineer of Fairchild Boats, Inc., of New York City, resumes his work in the editorial field. He is a former editor of The Rudder, and at the time of his resignation of this post a Personal Note containing a brief biographical sketch was published about him in the October, 1928, issue of the S.A.E. Journal.

Mr. White has been a Member of the Society and of the Metropolitan Section since 1924. Last year he served on the Publication Committee of the Metropolitan Section, and this year he is acting as a member of the Society's Grading Committee.

Foulois Chief of Materiel Division

News of considerable importance to aeronautical circles was contained in the recent announcement of the appointment of Brigadier-Gen. B. D. Foulois as chief of the Materiel Division of the Air Corps of the United States Army, with headquarters at Wright Field, Dayton.

General Foulois, who has been an Associate Member of the Society since 1925, formerly held the post of assistant chief of the Air Service, in the City of Washington. Upon the occasion of this latter appointment a Personal Note was published last year about General Foulois in the January issue of the S.A.E. Journal, in which his aeronautical activities in the service of the Army were briefly listed.

Applicants Qualified

BACKUS, TOM (J) engineer, Willys-Overland Co., *Toledo, Ohio.*

BROWN, HANSON AMES (A) vice-president, general manager, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

BUTTORF, HARRY E. (M) plant engineer, Fisher Body Corp., Division of General Motors Corp., Detroit; (mail) 41 North Avenue, *Highland Park, Mich.*

CAPLAN, HYMAN (A) purchasing agent of automotive equipment, treasurer, superintendent of maintenance, Gray Line, Inc., *Boston;* (mail) 1234 Washington Street.

CLEAVER, BENJAMIN JAMES (A) contact engineer, handling engineering contact with production, General Motors Truck Corp., Pontiac, Mich.; (mail) R. F. D. No. 4, *Milford, Mich.*

CLELAND, JAMES LEIPER (M) director, automobile department, Hamilton Technical Institute; (mail) 32 Dolewood Crescent, Westdale, *Hamilton, Ont., Canada.*

COGGINS, HERBERT (J) supervisor of mechanical inspection, General Motors of Canada, Ltd., *Walkerville, Ont., Canada;* (mail) 636 Victoria Road.

DENSHAM, ERIC WILLIAM (FM) service manager, Bristol Aeroplane Co., Ltd.; (mail) 4 Bayswater Avenue, Westbury Park, *Bristol, England.*

DOLAN, CHARLES H., JR. (A) in charge of aviation survey, Inter-Island Steam Navigation Co., *Honolulu, Territory of Hawaii;* (mail) 3069 Nuuanu Ave.

DORR, GEORGE NICKOLI (M) chief mechanical engineer, Metalwood Mfg. Co., 3362 Wight Street, *Detroit.*

EGLOFF, GUSTAV, DR. (M) Universal Oil Products Co., Chicago; (mail) *Riverside, Ill.*

EUKER, EDWIN M. (J) checker, chassis engineering, Hupp Motor Car Corp., *Detroit;* (mail) 2665 Gladstone Avenue.

FARREL-BIRMINGHAM CO., INC. (Aff.) 344 Vulcan Street, *Buffalo;* Representative: Kuhns, Austin, manager, gear department.

The following applicants have qualified for admission to the Society between July 10 and August 10, 1929. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

FOLLETT, W. H. (A) foreman, maintenance transportation, Paine Lumber Co., Ltd., *Oshkosh, Wis.;* (mail) 15 Walnut St.

FOOTE, E. T. (M) vice-president, Globe-Union Mfg. Co., 14-28 Keefe Avenue, *Milwaukee.*

FRANK, CLARENCE E. (J) layout man, chassis production drafting, Packard Motor Car Co., *Detroit;* (mail) 4229 Hurlbut Avenue.

FRINK, JAMES H. (J) assistant to manager, Washington Iron Works, *Seattle, Wash.*

GARNER, F. H., DR. (M) chief chemist, Anglo-American Oil Co., Ltd., Laboratory Department, 83 Albert Embankment, Vauxhall, *London S. E. 11, England.*

GITHENS, THOMAS FRANCIS (M) mechanical engineer, Cleveland Twist Drill Co., 1242 East 49th Street, *Cleveland.*

GLIDEWELL, JAMES E. (M) layout draftsman, calculations, Hall-Scott Motor Car Co., *Berkeley, Calif.;* (mail) 1630 University Avenue, Apartment 50.

GREGOR, MICHAEL (M) consulting engineer, Brunner & Winkle Aircraft Corp., 72-34 Charlotte Place, *Brooklyn, N. Y.*

HARDECKER, JOHN F. (M) chief draftsman, Naval Aircraft Factory, Navy Yard, *Philadelphia.*

HAY, MALCOLM (A) supervisor of new car deliveries, student in mechanical department, The White Co., Long Island City, N. Y.; (mail) 275 Lincoln Place, *Irvington, N. J.*

HENDERSON, M. B. (A) salesman, Motor Parts Co., 2215 Webster Street, *Oakland, Calif.*

HODAPP, GEORGE H. (A) assistant general manager, Penn Spring Works, Inc., Lock Street, *Baldwinsville, N. Y.*

JACK, W. E. (A) lubrication engineer, Skelly Oil Co., Lubricating Department, El Dorado, Kans.; (mail) Skelly Building, *Tulsa, Okla.*

JONES, FRANK HUBERT (A) assistant export service manager, Willys-Overland Crossley, Ltd., Stockport, England; (mail) Elmcroft, Penn, *Wolverhampton, England.*

JUDD, DONALD M. (A) salesman, Ferro Machine & Foundry Co., *Cleveland;* (mail) 3305 Ardmore Road, Shaker Heights.

KALCHTHALER, CARL W. (A) sales engineer, Hyatt Roller Bearing Co., 10-142 General Motors Building, *Detroit.*

KELLEY, RUSSELL T. (A) president, Hamilton Advertisers' Agency, Ltd., 17 Main Street, East, *Hamilton, Ont., Canada.*

LARSEN, VICTOR AUGUST (J) struct engineer, stress analysis, New Standard Aircraft Corp., Paterson, N. J.; (mail) 65 Valley Road, *Clifton, N. J.*

LENZ, H. F. (M) production manager, Kinner Airplane & Motor Corp., 635 West Colorado Boulevard, *Glendale, Calif.;* (mail) 1620 Idlewood Road.

LEWIS, GEORGE K. (A) director of engineering, Met-L-Wood Corp., 6755 West 65th Street, *Chicago.*

LINDSAY, CHARLES H. (A) resident engineer, American LaFrance & Foamite Industries, Inc., 1415 West Ninth Street, *Cleveland.*

LOMBARD, CHARLES WILSON (A) department head, automobile mechanics course, Murray Vocational School, *Charleston, S. C.;* (mail) 13 Varnum Avenue.

Motorboat Conference

(Concluded from p. 319)

hope of finding a better bearing than the regular bronze bearing which, up to the present time, gives longer service and smoother performance than any rubber-packed bearing the company has tested.

Cooperation Wanted on Electrical Problems

C. V. Williams, in his paper entitled, Marine Electrical Accessories and Wiring Problems, made a plea for cooperation from the boat builder and the engine manufacturer in making boating free from the annoyances and hazards caused by defective and inadequate electrical accessories. Generators are becoming overloaded, the waterproofing of ignition coils is becoming increasingly important, salt-water corrosion of electrical apparatus presents a problem, and the question of marine service of electrical equipment is a hard one to solve, declared the author. He said an attempt had been made to use the automobile type of electrical equipment in boats but this had not proven entirely successful.

Mr. Williams suggested that the motorcoach type of equipment, because of its more rugged construction and greater capacity, might prove more adequate. Mr. Smith and Mr. Kettering agreed that another important problem was that of keeping the water from the distributor, a problem which Mr. Williams admitted he had encountered that day in Detroit.

Results Hoped for from Meeting

At the close of the meeting Mr. Kettering expressed his gratification in the stimulating discussion of motorboating problems which this meeting had brought forth. He said we are living in an age when the public demands speed in any means of transportation. Water is 800 times as heavy as air, making it more difficult to travel fast through water than to attain speed on land, where the air offers the chief resistance, but he voiced the opinion that these greater difficulties would surely be overcome through such open discussion of problems, the recognition and definition of which are the first steps toward standardization. It is hoped, he said, that this meeting will mark the opening of a new era of increased service to the industry for the marine activities of the Society, and the start of a notable series of motor-boat meetings.

Carson Wins S.A.E. Boat Race

The S.A.E. Outboard Motorboat Race, held on Sunday afternoon at the Detroit Yacht Club, was hotly contested, with Kit Carson, of the Delco Remy Corp., the victor. Dwight Huss, of the Kermath Mfg. Co., came in second; Jim Wayman, of Marine Motors, Inc., third; Sidney Dresser, of the Kent Garage Investing Co., fourth; and J. Zubaty, of the A C Spark Plug Co., fifth.

Applicants for Membership

ALLEN, WILLIAM G., shop foreman, Allen Motor Co., *Elkader, Iowa.*

BALE, RALPH G., manager, Lincoln Division, Universal Auto Co., *Spokane, Wash.*

BENSON, BERNARD H., draftsman. Sewer Department, D. C. Government Department, *City of Washington.*

BLANC, FERNANDO, manager, F. Blanc & Co., *Turin, Italy.*

BLOOM, CARL R., store superintendent, Colyear Motor Sales Co., *Spokane, Wash.*

BOECK, EDWIN J., secretary-treasurer, Truck Equipment Co., Inc., *Buffalo.*

BOECK, ELLSWORTH R., president, Truck Equipment Co., Inc., *Buffalo.*

BOWLER, H. A., manager, City Tire Shop, *Spokane, Wash.*

BOYSEN, HERMANN, layout draftsman, American LaFrance & Foamite Co., *Elmira, N. Y.*

BROWN, ALEXANDER H., JR., engineer, General Electric Co., *Schenectady, N. Y.*

CHADBOURNE, LeRoy, engineer. Wright Aeronautical Corp., *Paterson, N. J.*

CHAMBERLAIN, CLARENCE D., president, Crescent Aircraft Corp., *New York City.*

CHANG, SIH-VAN, student engineer, General Railway Signal Co., *Rochester, N. Y.*

CONNER, JOHN F., automobile repair man, Beeson Brothers, *Spokane, Wash.*

CORPE, THOMAS HENRY, representative in charge of European operation, Fisher Body Service Corp., *Detroit.*

DE LE PAULLE, ANDREW H., general manager and secretary, Renault Selling Branch, Inc., *New York City.*

DICKINSON, WILLIAM, vice-president, secretary, Automotive Electric Co., *Spokane, Wash.*

EATON, P. W., superintendent of maintenance, Pacific Stages, Inc., *Portland, Ore.*

EVANSON, LEE A., owner, manager, Medical Center Garage, *Spokane, Wash.*

FAIRFIELD, WILLIAM A., special representative, National sales division, International Harvester Co. of America, *San Francisco.*

FIELDING, CHARLES EDWARD, assistant works manager, A. V. Roe & Co., Newton Heath, *Manchester, England.*

FREY, RUDOLF, draftsman, Western Reserve Air Motors Corp., *Cleveland.*

FROBES, C. R., assistant branch manager, International Harvester Co. of America, *Philadelphia.*

FRY, DAVE, service manager, Blackwell Motor Co., *Spokane, Wash.*

GOETSCH, HUBERT JOHN I., general service manager, General Motors South Africa, Ltd., *Porth Elizabeth, South Africa.*

GRAEBNER, OTTO F., chief engineer, Murray Corp., *Detroit.*

GRAHAMSLAW, WILLIAM HAYNES, consulting engineer and lecturer in automobile engineering, Motorists' Mutual Benefit Association, Ltd., *Edinburgh, Scotland.*

GRAY, ELMER E., proprietor, Gray's Garage, *Salt Lake City, Utah.*

GRIFFITH, M. O., chief engineer, powerplant, Crosley Aircraft Co., *Cincinnati.*

HAIDUCK, ANDREW FRANK, engineer, stress analysis, Bellanca Aircraft Corp., *New Castle, Del.*

HANKS, STEDMAN, president, Stedman Hanks & Co., Inc., *New York City.*

HANSHUE, HARRIS M., president and general manager, Western Air Express and Fokker Aircraft Corp. of America, *Los Angeles.*

HARMON, FRANK J., branch manager, International Harvester Co. of America, *Philadelphia.*

HARRIS, ERNEST W., executive engineer, Erie Malleable Iron Co., Automotive Wheel Division, *Erie, Pa.*

HAWLEY, SPENCER H., superintendent of maintenance, Auto Interurban Co., *Spokane, Wash.*

HERMANN, OTTO, president and chief engineer, Century Rotary Motor Corp., *Canastota, N. Y.*

HILDAHL, NORMAN E., garage superintendent, Continental Baking Co., *Spokane, Wash.*

HODSDON, C. H., head machinist, Nelson Motor Co., *Spokane, Wash.*

HODSDON, GENE F., service salesman, Wells Chevrolet Co., *Spokane, Wash.*

HOGUE, ARCH J., service manager, McCue Garage, *Laramie, Wyo.*

IJUIN, KIYOHIKO, general manager, Mitsubishi Aircraft Co., Ltd., Nagoya Works, *Nagoya, Japan.*

JACOBUS, DALE P., assistant on tests, motors and appliances, Pratt Institute, *Brooklyn, N. Y.*

JESSEN, GEORGE R., proprietor, Glove Garage, *Spokane, Wash.*

JOHNSON, LOUIS P., salesman, Colyear Motor Sales Co., *Spokane, Wash.*

JONES, T. ELMER, superintendent of repair shop, Beeson Bros., *Spokane, Wash.*

KELLEY, WILLIAM HAROLD, production manager, Brewster & Co., *Long Island City, N. Y.*

KEY, ROY PATTERSON, chief engineer, Canadian Vickers, Ltd., *Montreal, Que., Canada.*

KILLMEYER, CHESTER A., carbureter specification engineer, Tillotson Mfg. Co., *Toledo, Ohio.*

KURTH, LUROFF D., machinist, Colyear Motor Sales Co., *Spokane, Wash.*

KOBINATA, EKJIRO, mechanical engineer, Japanese Government Railways, *Tokio, Japan.*

LAGRONE, JOHN K., airplane distributor, Waco Aircraft Co., *Kansas City, Mo.*

LENGUADORO, JOSEPH A., mechanic on gasoline and electric trucks, Public Service Co. of Northern Illinois, *Chicago.*

LEWIS, PETER SAMUEL, shop foreman, Eldridge Buick Co., *Spokane, Wash.*

LITTELL, W. S., owner, Littell Machinery Co. *Spokane, Wash.*

MAST, W. A., shop foreman, Globe Garage, *Spokane, Wash.*

MATSON, RANDOLPH, chief engineer, Southwest Aviation Co., *Glendale, Calif.*

McCARRY, FREDERICK J., partner, Crescent Machine Works, *Spokane, Wash.*

MILLER, JOSEPH PAUL, design draftsman, Horace E. Dodge Boat Works, *Detroit.*

MOORE, JOHN B., president, Fleetwing Aircraft, Inc., *Lincoln, Neb.*

MOORE, ROBERT S., research and designing engineer, General Airmotors Corp., *Scranton, Pa.*

MOYSE, D. W., traveling district garage foreman, Shell Oil Co., *Spokane, Wash.*

NOFZ, HAROLD, tool and die designer, Bowen Products Co., *Detroit.*

NORCROSS, CHARLES M., service engineer, United Motors Service Corp., *New York City.*

NUNN, EWING D., secretary, Nunn-Landon Co., *Milwaukee.*

PAGE, GEORGE A., JR., design engineer, Curtiss Aeroplane & Motor Co., Inc., *Garden City, N. Y.*

PARRISH, RUSSELL JAMES, mechanical engineer, Chevrolet Aircraft Corp., *Indianapolis.*

PERRY, ROBERT J., sales promotion, C. R. Robinson Sales Co., *Detroit.*

PENNINGTON, JOHN HAWLEY, lubrication engineer, Vacuum Oil Co. Proprietary, Ltd., *Dunedin, New Zealand.*

PETERSON, OSCAR R., service manager, Thompson-Cadillac Co., *Spokane, Wash.*

PRADELLA, VICTOR W., foreman of body shop, Transport Motor Co., *Spokane, Wash.*

PREBLE, NORMAN H., vice-president and chief engineer, Mechanical Handling Systems, Inc., *Detroit.*

PUFFER, SAMUEL R., mechanical engineer, General Electric Co., River Works, *Lynn, Mass.*

RAWSON, HARRY H., superintendent, vice-president, Washington Machinery & Supply Co., *Spokane, Wash.*

RAYMOND, LLOYD E., metallurgist, Greenfield Tap & Die Corp., *Greenfield, Mass.*

ROGERS, P. B., assistant engineer, Great Lakes Aircraft Corp., *Cleveland.*

RUSSELL, F. H., vice-president, Curtiss Aeroplane & Motor Co., Inc., *Garden City, N. Y.*

SALMI, ARNO GUSTAV, production clerk, Nash Motors Co., *Milwaukee.*

SHORTHOUSE, BENJAMIN, director, Blackstock Engineering Co., Ltd., *London, England.*

SLIFER, W. J., president, W. J. Slifer & Co., *Easton, Pa.*

STARR, WESTOL JAMES, garage foreman, Standard Oil Co. of California, *Spokane, Wash.*

STENSTROM, JOSEPH F., service manager, Spokane Nash Motors, Inc., *Spokane, Wash.*

STONE, S. J., assistant general manager, Supreme Propeller Co., *Wichita, Kan.*

STOVER, GEORGE H., superintendent of maintenance and repairs, Ames Transfer Co., *New York City.*

SWIFT, STANLEY J., salesman, Cleveland Pneumatic Tool Co., *Cleveland.*

THORSEN, WALTER T., garage superintendent, Interstate Coach Co., *Spokane, Wash.*

THULIN, BJARNE, project engineer, powerplant section, General Motors Research Corp., *Detroit.*

URQUHART, STEPHEN DONALD, draftsman and office chief, Montreal Tramways Co., Bus Department, *Montreal, Que., Canada.*

VAN EATON, FRANK W., salesman, Colyear Motor Sales Co., *Spokane, Wash.*

VAUGHN, FLOYD, service foreman, Eldridge Buick Co., *Spokane, Wash.*

WALKER, ARTHUR P., territory representative, Colyear Motor Sales Co., *Spokane, Wash.*

WALKER, SYDNEY, works manager, Laycock Engineering Co., Ltd., Millhouses, *Sheffield, England.*

WALTON, ALBERT, plant engineer, Budd Wheel Co., *Detroit.*

WILLIAMS, PERCY S., general manager, Hall-Scott Motor Car Co., *Berkeley, Calif.*

WILLIAMS, SYDNEY NORMAN, works manager, assembly plant. Turner Brothers, *Melbourne, Victoria, Australia.*

WILLS, S. JACK, service manager, William T. Barnard, Inc., *Spokane, Wash.*

WRIGHT, HARRY EDGAR, superintendent of service. Hull-Stewart Motors, Inc., *Spokane, Wash.*

YOUNG, CLARENCE M., special representative in charge commercial sales, Sun Oil Co., *Detroit.*

ZIRCKEL, HAROLD W., district mechanic, Associated Oil Co., *Seattle, Wash.*

Notes and Reviews

AIRCRAFT

Tables for Pressure of Air on Coming to Rest from Various Speeds. Report No. 316. By A. F. Zahm and F. A. Louden. Published by the National Advisory Committee for Aeronautics, City of Washington. [A-1]

In Technical Report No. 247 of the N.A.C.A., theoretical formulas are given from which was computed a table for the pressure of air on coming to rest from various speeds, such as those of aircraft and propeller blades. In that report, the table gave incompressible and adiabatic stop-pressures of air for even-speed intervals in miles per hour and for some even-speed intervals in knots per hour. Table II of the present report extends the above-mentioned table by including the stop pressures of air for even-speed intervals in miles per hour, feet per second, knots per hour, kilometers per hour, and meters per second. The values of pressures in the new table are also more exact than the values given in the previous table.

To furnish the aeronautical engineer with ready numerical formulas for finding the pressure of air on coming to rest, Table I has been derived for the standard values specified below it. This table first presents the theoretical pressure-speed formulas and their working forms in centimeter-gram-second units as given in N.A.C.A. Technical Report No. 247, and furnishes additional working formulas for several special units of speed.

Wind-Tunnel Pressure Distribution Tests on a Series of Biplane Wing Models. Part I. Effects of Changes in Stagger and Gap. Technical Note No. 310. By Montgomery Knight and Richard W. Noyes. Published by the National Advisory Committee for Aeronautics, City of Washington. [A-1]

This report furnishes information on the changes in the forces on each wing of a biplane cellule when either the stagger or the gap is varied. The data were obtained from pressure-distribution tests made in the atmospheric wind-tunnel of the Langley Memorial Aeronautical Laboratory. Since each test was carried up to 90-deg. angle of attack, the results can be used in the study of stalled flight and of spinning as well as in the structural design of biplane wings.

The Use of Wheel Brakes on Airplanes. Technical Note No. 311. By Thomas Carroll and Smith J. DeFrance. Published by the National Advisory Committee for Aeronautics, City of Washington. [A-1]

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

Tests to determine the effect of wheel brakes on the landing run of an airplane under various conditions of load and at various wind velocities are described and the results presented. The advantages of the use of brakes in reducing the landing run and in increasing the facility of ground maneuvering are discussed, together with methods of operation and application.

Technical Memoranda Nos. 521, 522, 524, and 525. Published by the National Advisory Committee for Aeronautics, City of Washington. [A-1]

Translations of the following articles were issued during July and August by the National Advisory Committee for Aeronautics:

Wings with Nozzle-Shaped Slots. By Richard Katzmäyr. Translated from *Berichte der Aerodynamischen Versuchsanstalt in Wien*, vol I, no. 1, 1928. 28 pp., illustrated.

The Analysis of Aircraft Structures as Space Frameworks Method Based on the Forces in the Longitudinal Members. By Herbert Wagner. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Aug. 14, 1928; 35 pp., illustrated.

Lautal as a Material for Airplane Construction. By Paul Brenner. Translated from 1928 Yearbook of the Deutsche Versuchsanstalt für Luftfahrt; 26 pp., illustrated.

Buckling Tests of Light-Metal Tubes. By August Schroeder. Translated from 1928 Yearbook of the Deutsche Versuchsanstalt für Luftfahrt; 18 pp., illustrated.

Soundproofing of Airplane Cabins. By V. L. Chrisler and W. F. Snyder.

Published in *Bureau of Standards Journal of Research*, May, 1929, p. 897. [A-1]

This is the first report of an investigation for the purpose of developing practical methods for reducing noise in the cabins of airplanes. The study is being carried out by the Bureau of Standards for the Aeronautics Branch of the Department of Commerce. It is recognized that it is most desirable to reduce the noise as much as possible at its source. It may be possible to reduce the noise of the propeller, and more efficient exhaust mufflers may be developed, but at present the soundproofing of the cabin seems to afford the most promising line of attack.

The present article contains a report of the work done in determining the structure which will give the maximum amount of sound insulation for a minimum weight.

Various small structures were tested at frequencies varying from 150 to 1120 cycles per second to determine the best structure available within the allowable limit of weight. A test flight was made in a treated cabin and it was found that the noise in the cabin under operating conditions was about the same as in a railroad coach in motion. The structure was also found to be an excellent heat insulator, and should make the cabin comfortably warm even in the coldest weather or at great altitudes.

Bedeutung der Normen für die Luftfahrt. By W. Caspari and M. Lehl. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, June 14, 1929, p. 273. [A-1]

So firmly has the value of standards to industry become established that to expound further on the subject seems superfluous, state the authors. However, although the aircraft industry as a whole has fallen into line with the general view, some few voices have been raised in protest. To these this article is a reply.

The main objections raised are that standards have no significance to the aircraft industry since there is no mass production, that they restrict development and introduce items of extra cost. Besides answering these objections, the authors dilate on the advantages of standards, pointing out that mass production must come if the aircraft industry is to prosper, that even when production has not assumed these proportions standards tend to lessen manufacturing costs, and, even more important, that the cooperative work on standards will breed a helpful spirit of cooperation in other fields. Other

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considerations dwelt upon are the importance to the aircraft operator of standard parts, the increase in the reliability of aircraft through their use, and, finally, the importance of international standards if Germany is to build up an export trade.

A list is given of the standards accepted and in prospect.

Technische Besonderheiten in der Baulichen Entwicklung der Rohrbach-Flugboote. By Gotthold Mathias and Adolf Holzapfel. Published in *Zeitschrift für Flugtecknik und Motorlufschiffahrt*, July 15, 1929, p. 334. [A-1]

The outstanding performance of the Rohrbach-Romar, now the largest flying-boat in the world, during its various trials last month have demonstrated, assert the authors, that the design and construction methods embodied in this craft are fundamentally correct. Ability of the craft to take off quickly, attain altitude with a heavy load, its seaworthiness and maneuverability, all bear witness to the value of research and test work that are the basis of its development.

In this article the authors endeavor to present, simply and without the introduction of abstract theories, the special features that distinguish the craft and give it its peculiar abilities. The discussion is grouped under six headings: Wing-Truss Structure; Hull; Pontoons; Engine Mounting; Starting and Maneuverability; and Flight Performance.

Aeroplanes, Seaplanes and Aero Engines. By P. H. Sumner. Published by Crosby Lockwood & Son, London; 292 pp., illustrated. [A-1]

This is the second volume on the science of flight and its practical application written by this author. The first volume, entitled, Airships and Kite Balloons, dealt with aerostatics, construction and development of the dirigible, and the airship in flight, and covered a record of performance of airships.

The present work deals principally with the heavier-than-air craft, and places before the reader the products of British industry and endeavor in this field.

A few of the earlier airplanes are described in the introduction. Chapters are devoted to Aerodynamics, The Airscrew, The Engine and The General Design and Construction of Aircraft. The better-known airplane engines and airplanes and seaplanes of British make are described, with accompanying specifications and illustrations. A chapter on aeronautic instruments is also included.

Weather and the Airplane. A Study of Model Weather-Reporting Service Over the California Airway. By Edward H. Bowie. Published by the Daniel Guggenheim Fund for the Promotion of Aeronautics, Inc., New York City; 27 pp., illustrated. [A-4]

A complete aeronautical weather-reporting service was installed on the airway between Los Angeles and San Francisco in June, 1928. This undertaking was sponsored by the Guggenheim Fund for the period of a year, in cooperation with the Pacific Telephone & Telegraph Co., the Air Service of the Army and Navy, the Department of Commerce, and the Weather Bureau. The service was established to demonstrate the necessity and value of a permanent system of this kind which would eventually include all the Nation's airways. According to this survey of the operations and results of the California demonstration, the service has proved an unquestioned success.

The information supplied by the station has also been used by the Automobile Club of Southern California in advising tourists of weather and temperature likely to be encountered in traveling from place to place, and arrangements are now being made to operate a mobile meteorological radio-receiving station for use in connection with forest-fire prevention and suppression.

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BODY

Le VIIIe Concours d'Elégance de l'Auto. By René Charles-
Faroux. Published in *La Vie Automobile*, June 25, 1929,
p. 231.   [B-1]

Like our annual Salons, the Concours d'Elégance is an
exhibition of fine body-work of the special-design or cus-
tom-built type. This eighth showing is said to have sur-
passed those of all previous years, in both numbers and
beauty of vehicles, the prevailing tendency being toward a
purity of exterior line.

The winner, the "royal Bugatti," is asserted to be espe-
cially notable, not only because it is a triumph of design,
but because in its construction Weymann, the spokesman
for fabric, has for the first time utilized some sheet metal.
How the body builder explains this, as not an abandonment
of his principles but as the logical avenue of development
toward the desired flexibility, is told in this article.

Other prize winners, one intended to intrigue the femi-
nine eye, and two distinguished for their originality, are
described. A closing observation of the author is that the
combination of American chassis with the regular produc-
tion bodies compares very unfavorably with the same
chassis equipped with French-built bodies.

**New Body Designs May Be Derived from Lowness of Front-
Drive Cars.** Published in *Automotive Industries*, June
22, 1929, p. 944.   [B-1]

That front-drive cars will provide the industry with some-
thing new in body design is the prediction of E. T. Pear-
sons, body designer of the Baker-Raulang Co., quoted in
this article. Mr. Pearsons points out that the mechanism
of the automobile is so well standardized that the success
of an individual car depends largely upon its appearance
or the comfort it provides. He says:

> In both these respects it has been the growing
> custom of late to borrow designs from a manufac-
> turer whose particular cars are selling well, with a
> steadily increasing tendency to keep away from
> radical changes in appearance, and confining innova-
> tions more or less to the hood and radiator, and to
> some extent to body moldings.

He declares, however, that if the engineering department
is supplying a mechanism which presents a new and valu-
able sales argument, it offers the possibility of giving the
body a new treatment individually expressing the new
mechanical design. Furthermore, he suggests, manufac-
turers turning out both front and rear-wheel-drive cars
may use the former to try out new ideas in body design,
which, if proved desirable, can be adopted in the standard
cars.

The lowness of the new type offers the greatest field for
modifying body design, according to Mr. Pearsons. The
manufacturer has the choice of lowering the over-all height
to the full amount made possible by the change in mecha-
nism, or he can use part of it in increasing headroom, re-
designing doors and so forth. Experimental designs
produced by the Baker-Raulang Co., illustrate the article.

CHASSIS PARTS

**Load Distribution in Gears Improves as Tooth Contacts In-
crease.** By R. V. Baud and R. E. Peterson. Published in
Automotive Industries, June 8, 1929, p. 873.   [C-1]

In this paper, read before the American Gear Manufac-
turers Association, the authors point out that when two
teeth of a gear are carrying the load, it cannot be inferred
that each tooth takes half the load. On the other hand,
the distribution of load depends on the elasticity of the
teeth as a function of their position along the line of action
and also on tip relief and tooth errors. The paper pre-

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sents a method of solving the load-division problem analytically, and determines by photo-elastic tests some general stress relations for gears in which the number of teeth carrying the load varies.

EDUCATION

The Engineer, His Work and His Education. By Robert Lemuel Sackett. Published by Ginn & Co. 196 pp. illustrated.   **[D-3]**

Fifteen thousand students each year enter engineering courses in the colleges and universities of the United States. A third of these students, according to recent statistics, drop out at the end of the first year. One of the principal causes of this high rate of elimination is the high-school student's lack of information about engineering as a profession and the college training that prepares him for it. The author, who is dean of engineering at the Pennsylvania State College, has written this book for the guidance of boys who are contemplating engineering for their life work.

The book makes available the findings of an investigation of engineering education carried out, with the support of the Carnegie Corporation, through the initiative of the Society for the Promotion of Engineering Education, and analyses the various branches of engineering practice: architectural, civil, electrical, mechanical, industrial, chemical, mining and metallurgical. In connection with each of these branches, the author gives a brief history, a description of the types of work included, the best training for that branch of engineering, and the opportunities for advancement offered in each field.

The final chapter discusses the esthetic, cultural and romantic elements in engineering, and an appendix gives short biographies of engineers who have helped to make history, including Leonardo Da Vinci, James Watt, George Westinghouse, Herbert C. Hoover, Charles M. Schwab and others.

ENGINES

The Angular Distortion of Crankshafts. By C. A. Norman and K. W. Stinson. Engineering Experiment Station Bulletin No. 43. Published by the Ohio State University, Columbus, Ohio. 20 pp., illustrated.   **[E-1]**

Since the presentation of a paper on this subject before the Society, the authors' attention was called to a paper by B. C. Carter appearing in *Engineering* for July 13, 1928, entitled, An Empirical Formula for Crankshaft Stiffness in Torsion. The formula referred to in the English paper was derived from observations on the distortion of crankshafts as a whole. Messrs. Norman and Stinson have, in this bulletin, republished in somewhat greater completeness their experimental work; made certain improvements and amplifications in the formulas derived, and set down the results of the application of these formulas to Carter's test material.

Roots Supercharger on Soucek Plane Proves Efficiency of Blower Type. Published in *Automotive Industries*, June 15, 1929; p. 911.   **[E-1]**

The plane with which Lieut. Apollo Soucek, U.S.N., recently broke the altitude record was equipped with a Roots blower-type supercharger, as developed by the National Advisory Committee for Aeronautics. Its performance seems to prove the efficiency of this type for altitude flying, the author of this article contends. While Roots blower-type superchargers have been used to a considerable extent on automobile engines, especially by Mercedes, in aircraft work the centrifugal-type supercharger has been used almost exclusively so far. But the N.A.C.A. set out some years ago to develop a blower type of supercharger and produced a design which has been tested extensively in the

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laboratory and in flights, and has shown its capabilities in a most striking way.

The design, construction and operation of this type of supercharger is described and its advantages over the reciprocating type, the sliding-vane or eccentric type, and the centrifugal type are pointed out.

Temperature and Pressure Effects upon Engine Power Development. By Daniel Roesch. Published in *Automotive Industries*, May 11, 1929, p. 732.   [E-1]

The power developed by an internal-combustion engine is dependent upon the number of British thermal units in the charge taken into the cylinder. The temperature and pressure of the charge in the cylinder and the volumetric efficiency, by card, are factors which determine the B.t.u. in the charge. Since engines are tested at various laboratory temperatures and pressures, it is essential, Professor Roesch contends, to convert all test data to some standard of temperature and pressure, and to know the general effects of variation in the observed temperature and pressure upon the power developed. The author discusses the practicability of various points of temperature measurement and describes his experimental work on this problem. The application of a correction factor to low-volatility-fuel engines is also considered.

Trois Moteurs Diesel à Grande Vitesse. By H. Petit. Published in *La Technique Automobile et Aérienne*, second quarter, 1929, p. 600.   [E-1]

To Germany, the birthplace of the Diesel engine, the author goes for news as to the latest developments in high-speed powerplants of this type. He brings back descriptions of three engines. The Deutz falls into the antechamber class, but, unlike others of this type, the antechambers are to the side instead of in line with the main working cylinders. The Krupp, made in either four or six cylinders, is distinguished by free use of light alloys in its construction, the pistons and connecting-rods being of these materials. The Koerting is to be noted for its method of fuel-injection, which is described.

L'Equipment Aéronautique. Published in *L'Aéronautique*, May, 1929, p. 151; June, 1929, p. 187.   [E-1]

Deprecating the title "accessories" as applied to certain items of airplane and airplane-engine equipment, the author terms them instead "essentials." So important have they seemed that a systematic investigation has been made to obtain information of the different types in all categories now being used. The results of this survey are to be embodied in a series of articles. Only parts of French manufacture or those of foreign origin that have gained a secure foothold on the French market will be described, and more space will be devoted to novelties than to standard devices that are familiar through usage.

The first article here noted is devoted to fuel-feeding systems and is divided into two parts, one dealing with tanks, the other with pumps. The second article takes for its province carbureters and carbureter accessories. In each case some general discussion precedes the detail descriptions of individual makes, the preface to the tank section, for instance, dealing with material characteristics, design requisites and tests of the entire part. Bibliographies and patent surveys form helpful supplements for those desiring to pursue the subject further.

HIGHWAYS

The Effect of Increased Speed of Vehicles on the Design of Highways. Reported by A. G. Bruce. Published in *Public Roads*, March, 1929, p. 11.   [F-1]

Taking into account the more liberal legal speeds, the greater possible speed due to improved roads and cars,

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with the difficulty in rigidly enforcing a speed limitation, it is estimated that the average speed on the open road today is fully 20 m.p.h. greater than it was 10 years ago.

The increased volume and speed of motor-vehicle traffic require smoother and wider road surfaces, easier curves, wider shoulders, shallower ditches, greater superelevation of curves, more extensive use of vertical curves, longer vertical curves at the top of hills, greater sight-distance on both horizontal and vertical curves, avoidance of compound curves, more adequate guard rails, better protection at railroad grade-crossings, and special treatment of intersections of heavy-traffic highways. The report covers each problem, giving graphical and statistical results of the Bureau of Public Roads Survey.

Highway Construction Administration and Finance. By E. W. James. Published by the Highway Education Board, City of Washington; 120 pp., illustrated.   [F-1]

The papers brought together in a single volume in this publication are by E. W. James, chief of the Division of Design, United States Bureau of Public Roads, and first appeared in the engineering journal, *Ingenieria Internacional*.

In this series, Mr. James has concisely described the principles and practices of modern highway development, with emphasis on the fundamental importance of planning the highway system. The papers as a whole present a comprehensive view of engineering economics and the technique of modern highways that should prove helpful to the highway engineer and the highway administration in accomplishing their part in large highway programs.

MATERIAL

The Accurate Determination of the Gasoline Content of Natural Gas and the Analytical Separation of Natural Gases by Isothermal Fractional Distillation. By Martin Shepherd. Published in the *Bureau of Standards Journal of Research*, June, 1929, p. 1145.   [G-1]

This paper describes a method for the accurate determination of gasoline in natural gas. The determination involves a special separation of the natural gas by fractional distillation at low temperatures and pressures. A recombination of the resultant fractions is made in such a way that it is possible to determine the maximum amount of hydrocarbon condensate present in the original gas which possesses any given vapor pressure at any given temperature. Apparatus and procedures are described in detail, analytical results given, and a direct comparison made with existing field and laboratory methods. The paper is, indeed, a simple instruction book for anyone engaging in this work.

Bearing Bronzes With and Without Zinc. By H. J. French and E. M. Staples. Published in *Bureau of Standards Journal of Research*, June, 1929, p. 1017.   [G-1]

Within the last three years an extended study has been made of the wear and mechanical properties of copper-tin-lead alloys widely used in railroad bearings. The study was made by the Bureau in cooperation with the Chicago Bearing Metal Co. and the Magnus Co., of Chicago. The purpose of the investigation was twofold: to develop a laboratory testing technique for bearing metals and to find the reasons for the wide variations in the specifications of different carriers for bearings for similar conditions of service. Test methods are described and experimental results given in detail.

The general conclusions are drawn that bronzes containing less than 4 per cent of tin are unsuited for general bearing service, since they have low resistance to deformation and wear rapidly in the absence of lubrication; that bronzes having less than about 5 per cent lead seem to be suited only for service where lubrication can be main-

tained: that bronzes containing more than about 5 per cent lead are best able of any of the groups studied to operate for short periods in the absence of lubrication; and that the results seem to justify the conclusion that the effects of zinc up to 4 per cent are generally small and may be insignificant in comparison with changes in properties readily produced in bronzes from variations in foundry practice.

MISCELLANEOUS

Automatic Plating Machinery. By Edwin M. Baker. Published in *Industrial and Engineering Chemistry*, May, 1929; p. 400.   [H-3]

Manual and automatic plating operations are described and contrasted by the author, and the relationship of labor costs, thickness of deposits, and sequence of operations to automatic plating-methods are discussed.

The general conclusions drawn by the author are that still plating tanks are justified only if the volume of work is small or if the plating time is extremely short; that semi-automatic tanks cost only a small percentage more, if the comparison is made on the basis of the completed installation, including generators; and that semi-automatic operation usually will eliminate at least 50 per cent of the labor required for still tanks, while fully automatic equipment has its application in the plant of the large manufacturer.

However, if the process is sufficiently worked out in advance and is adaptable to fully automatic equipment, Mr. Baker points out the following advantages: (*a*) saving labor, eliminating up to 90 per cent of that required for hand methods; (*b*) assuring more nearly uniform quality than can be had by other methods; (*c*) reducing required size of generating equipment, since this can be continuously kept under full load, with resultant elimination of peak or overload capacity otherwise required to compensate for idle time involved in manual methods; (*d*) reduction of percentage of work rejected, and (*e*) predetermined productive capacity for a fixed working period.

The article closes with the warning that unless the production is reasonably uniform and of sufficient volume to warrant the larger investment required for fully automatic equipment, this type of equipment may prove an expense rather than an economy.

Report of the National Screw-Thread Commission. Published by the Department of Commerce, Bureau of Standards; City of Washington. Revised, 1928; 261 pp., illustrated.   [H-3]

This is the third report of the National Screw-Thread Commission, being a revision of the 1924 report. The general arrangement of the previous report has been retained with the exception that specifications for threading-tools have been removed from the body of the report, extensively revised, and included as an appendix. A number of other important revisions have been made and considerable new material has been added.

Economies Which May Be Effected in Power Transmission. By W. W. Nichols. Presented at the meeting of the American Society of Mechanical Engineers, Rochester, N. Y., May 13 to 16, 1929.   [H-5]

Power-transmission equipment is not given careful consideration by management from the standpoint of economical maintenance, contends the author, reporting for the Machine-Shop Practice Division of the A.S.M.E. He argues that the equipment should not be left to the supervision of some old-time millwright. Belting is not given close enough inspection upon its receipt to determine whether it meets all the requirements laid down by the specifications for its purchase. Many machines used in production work are

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overbelted, little attention being given to the correct determination of the size of belt necessary for the work. Heavier belts could be profitably installed. By this means, unnecessary wear and tear upon countershaft clutches would be eliminated. More attention should be given to the application of the correct size of motor to individually motor-driven tools, from both an initial and a maintenance standpoint.

Mechanical Power Transmission. By William Staniar. Published by McGraw-Hill Book Co., Inc., New York City; 409 pp., illustrated. [H-5]

The author claims that his book is the first practical treatise on the mechanical transmission of power. The results of research and investigation of this subject, he contends, have been generally of a technical nature and are found only in the transactions of engineering societies and in the files of technical publications. Mr. Staniar has endeavored to present, without recourse to formulas, equations, and calculus, non-technical working data for men in charge of power transmission who have had no training in the theories of motion or power.

The book gives the answers to such every-day problems as what type of belt to use for a given mechanical and atmospheric condition; what width and thickness of belt should be used for a given horsepower, speed and pulley diameter; and what methods of belt joining to employ for given conditions. The author also deals with many other accessories that constitute the power-transmission system, such as plain or self-oiling bearings, antifriction bearings, clutches, shafting, pulleys, collars, chains of all descriptions, short-center driving mechanisms, and speed reducers.

MOTOR-TRUCK

Entwicklungstendenzen im Bau von Lastanhängern. By Karl Beneke. Published in *Der Motorwagen*, May 10, 1929, p. 271. [K-1]

An attempt is made in this article to detect, from recent progress made in trailer design, what will be the general trend of development. Such progress has been slight until recently, the author asserts. While influenced by motor-truck design, trailer development has lagged far behind. However, the recent increase in the speed and power of trucks has given to trailer development an impetus which has found expression in such improvements as strengthened frame-members and heavier construction of parts.

Such topics as tires, wheels, axles, springs, frames, loading arrangements, brakes and general equipment are discussed. The merits of steering by a pivoted bogie and by pivoted levers are examined and an effort is made to forecast developments along these lines.

Aluminum-Alloy Bodies for Trucks Possess an Economic Advantage. By P. M. Heldt. Published in *Automotive Industries*, June 22, 1929, p. 938. [K-1]

Since 1926, truck and trailer bodies in limited numbers have been built of aluminum-alloy shapes and sheets. The chief incentive to use aluminum for this purpose seems to have been the legal restrictions imposed by most of the States on the gross weight of vehicles using the public highways. By lightening the bodies, not only is it possible to carry additional loads legally, but this can be done without increasing the usual wear and tear on the chassis coincident with the use of conventional truck bodies.

The author analyzes the possible savings through the use of aluminum-alloy bodies and cites a specific example. Aside from the advantage of the increase in pay-load without additional operating costs, except the higher first cost, an additional advantage is less rapid deterioration. With less gross weight, less gearshifting is required and better time can be made. Aluminum bodies also have a higher

scrap value than other types of body when they are worn out, but it is obviously too early to draw any comparisons between the life of this type and the standard type.

PASSENGER CAR

Réflexions sur les Vingt-Quatre Heures du Mans. By Marc Chauvierre. Published in *La Vie Automobile,* July 10, 1929, p. 251.   [L-1]

The 24-hr. race at Mans this year, writes the author, was not only a victory for the visiting contestants from across the Channel and the Atlantic, who carried off the laurels, and a defeat for the French cars, but was a triumph of the foreign automotive industry over that of France. For years France has discounted the worth of foreign cars for high-speed open-country driving; she can no longer do so. Of the 28 entries, 18 were foreign makes. Eight of these, or almost 50 per cent, finished. Of the 10 French competitors only, 2, or 20 per cent, completed the run. In the main, the cars having the larger engines were English and American, France being represented only in the small-engine class.

From his observations the author concludes that most of the break-downs were due to engine failure. He also points out that, of the six cars equipped with superchargers, only one finished. He briefly describes the entries and the course of the race, and warns the French automotive industry that loss of supremacy in public favor may follow loss of supremacy on the race track.

Réflexions Techniques sur le Grand Prix de l'A.C.F. Published in *La Vie Automobile,* July 10, 1929, p. 247.   [L-1]

Two points of special interest this year distinguished the important French racing event, the Grand Prix of the Automobile Club of France. For the first time a maximum gasoline and oil consumption and a minimum weight was set for all contesting cars. In the second place, the competition typified the struggle for preeminence between two types of engine: the eight-cylinder poppet-valve supercharged Bugatti, which finished first, representing one school of design; and the four-cylinder sleeve-valve unsupercharged Peugeot, which crossed the line 1 m. 19 sec. later, making a good showing for the other school. Another Bugatti finished third, 8 sec. behind the Peugeot.

An answer to the opponents of supercharging is also seen in the results of the race, since the Bugatti and the Peugeot had at the close the same quantity of fuel remaining and presumably had the same fuel consumption per horsepower-hour.

Le Travail à la Chaîne dans les Fabrications en Série. By A. C. Published in *Le Génie Civil,* June 8, 1929, p. 541.   [L-5]

Interest in "line production," which involves the breaking down of the manufacturing process into the most elementary operations, the careful timing of these operations and the progressive movement of the piece under fabrication through the series, has become widespread in industrial circles in France. Stimulating and signalizing this interest is a prize offered by the Comité National de l'Organisation Française for the best paper describing a plant manufacturing under this system. The subject of the paper may be either a factory in operation or one only planned, although preference will be given to descriptions of undertakings that already have proved their utility and efficiency in service. The author must have taken an active part in the organization he discusses, either as director or assistant.

This paper explains the theory of line production, outlines the various types of conveyor system, overhead and ground, and, as a concrete example, surveys the methods and equipment of the Citroën factory.

Personal Notes of the Members

(Continued from p. 313)

LePage with Kellett Aircraft Corp.

W. Laurence LePage, a Junior Member of the Society since 1924, recently announced the severance of his connection with Pitcairn Aviation, Inc., of Philadelphia, in which he acted in the capacity of assistant to vice-president, to become associated with W. Wallace Kellett, president of the newly-organized Kellett Aircraft Corp., also located in Philadelphia. The new concern will develop and manufacture Autogiros for private and commercial purposes.

A news item about Mr. LePage appeared in the columns of Personal Notes in the July, 1928, S.A.E. JOURNAL, at the time of the publication of his book entitled, The ABC of Flight, which dealt with the fundamental principles of flight and their application. This Note contained a brief sketch of Mr. LePage's activities in the field of aviation.

Drake Resigns from S K F

Charles L. Drake has brought to an end his long affiliation with the S K F Industries, Inc., of New York City, to join the Yale & Towne Mfg. Co., of Stamford, Conn., in the capacity of assistant to George W. Wilder, manager of the automotive division, Detroit.

Gaining his practical experience with Fairbanks, Morse & Co., of Beloit, Wis., Mr. Drake entered the service of the S K F Ball Bearing Co. in 1914 as a designer in the engineering department. This connection was interrupted in 1917 by the World War, during which he served for two years in the United States Army. In 1919 he returned to S K F and became identified with the sales department, being transferred shortly afterward to the Detroit office. In 1922 Mr. Drake entered the sales department of the Swedish Charcoal Steel Products, Inc., located in New York City, but renewed his connection with S K F one year later.

Mr. Drake, who has held an Associate membership in the Society since 1923, has been prominent in the work of the Metropolitan Section, which he joined in 1925. He served as its treasurer in 1928 and this year is representing the Section on the National Sections Committee.

Elliott A. Allen, formerly Pacific Coast manager of the New Departure Mfg. Co., of Bristol, Conn., has resigned to accept a position as general sales manager of the Peerless Pump Co., of Los Angeles.

Harvey L. Anderson has become identified, as junior aeronautical engineer, with the Aeronautics Branch of the Materiel Division, Wright Field, at Dayton, Ohio. He was a former student at the University of Michigan.

R. B. Beisel has resigned as chief designer for the Curtiss Aeroplane & Motor Co., in Garden City, Long Island, to join the Spartan Aircraft Co., at Tulsa, Okla.

M. M. Botnick, until recently general manager and chief engineer of the Charles D. Schmidt Corp., of New York City, has become affiliated with Yale & Towne, Inc. He will be assistant to the manager of the material-handling division of the company in New York City.

James Wesley Brown lately assumed the presidency of Guaranteed Maintenance, Inc., in Los Angeles. His former connection was with the Moreland Motor Truck Co., of San Francisco, as district manager in northern California.

William J. Carthaus has relinquished the posts of president and treasurer of Correct Motor Fuels, Inc., of Alton, Ill., to become affiliated with the Shaffer Oil & Refining Co., in Chicago.

Robert Wilcox Case, formerly a student of aeronautical engineering at the Massachusetts Institute of Technology, has been employed by the Auburn Automobile Co., of Dayton, Ohio, in the capacity of aeronautical engineer.

Lee L. Cass, now acting as development engineer for Fairbanks, Morse & Co., of Three Rivers, Mich., formerly held the position of engineering manager of the western division of the Hyatt Roller Bearing Co., in Chicago.

Personal Notes of the Members
Continued

J. Edwin Coates has relinquished the position of laboratory test engineer with the Ethyl Gasoline Corp., in Detroit, to become affiliated with the Standard Steel Propeller Co., in Pittsburgh, as propeller engineer.

Eugene O. DeBruler, a student of mechanical engineering at Ohio State University, has been employed by the Surface Combustion Co., at Toledo, as draftsman.

Frank A. Dobbe, formerly motorcoach engineer with the General Motors Truck Corp., at Pontiac, Mich., has entered the service of the Cessna Aircraft Co., in Wichita, Kan.

Cady B. Durham, former vice-president and assistant general manager of the Buick Motor Co., has been appointed to the staff of the president of the General Motors Corp. His headquarters will be at Flint, Mich.

Earl V. Farrar, now acting in the capacity of draftsman and designer for the Wright Aeronautical Corp., at Paterson, N. J., formerly instructed classes in practical mechanics at Purdue University.

Howard A. Felten, engineering student at the University of Wisconsin, recently joined the Milwaukee Forge & Machine Co. in the capacity of apprentice engineer.

C. E. Frudden, until lately sales engineer for the Buda Co., Harvey, Ill., has joined the Allis-Chalmers Mfg. Co., in Milwaukee, as an engineer in the tractor division.

Herbert Gfroerer has been made special representative by the Olds Motor Works, of Lansing, Mich. Prior to establishing this connection he was district representative for the Dodge Brothers Corp., in Detroit.

John Graham recently assumed the presidency and general managership of the Weymann American Body Co., in Indianapolis. Previously he was president of the Holbrook Co., of Hudson, N. Y.

Manford P. Hanson, who recently completed an engineering course at the University of Minnesota, is now pursuing the college graduate training course given by the Frigidaire Corp., located at Dayton, Ohio.

K. R. Herman, formerly chief draftsman of the Divco-Detroit Corp., has been advanced to the post of chief engineer of this Detroit company.

Announcement was recently made of **John G. Hill's** affiliation with the New York Branch of the Old Motor Works, of Lansing, Mich. He will act as service promotion representative.

Harold D. Hoekstra, a former student at the University of Michigan, has taken up the duties of chief airplane engineer with the Crosley Aircraft Co., of Cincinnati.

B. Jerome has given up his position as assistant chief engineer of the Olds Motor Works, of Lansing, Mich., but has not announced his plans for the future.

A. J. Langhammer, previously identified with the manufacturing division of the Chrysler Corp., of Detroit, is now factory manager of Dodge Brothers (Canada), Ltd., at Toronto.

Walter R. Lindsay has assumed the secretaryship of Woodruff Patents, Inc., at Newark, N. J. He formerly was associated with the General Motors Export Co., in New York City.
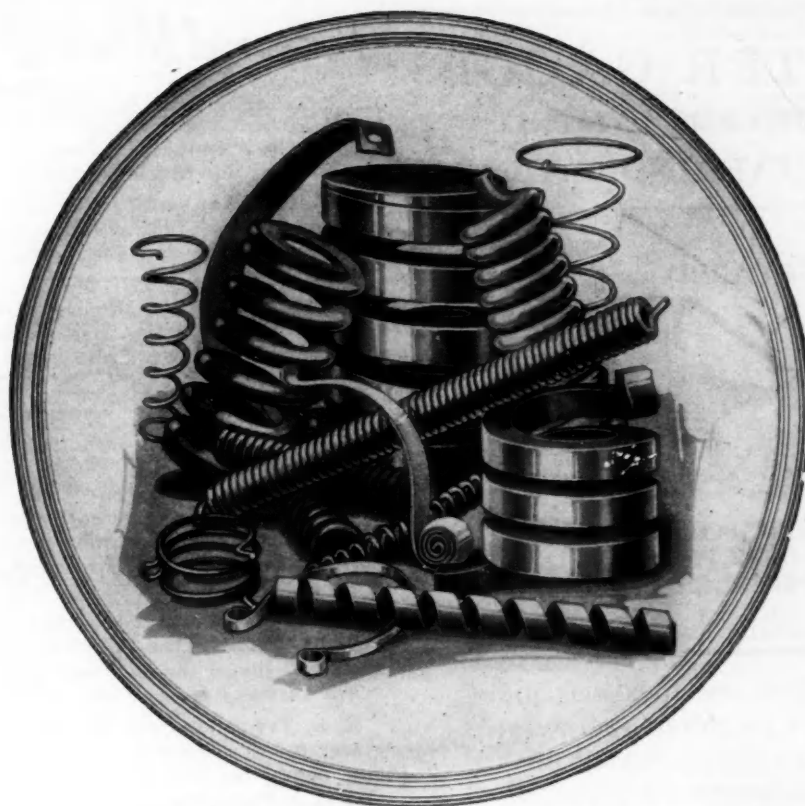
P. E. Miquelon, a consulting engineer, recently established a connection with the Universal Products Co., in Detroit.

Charles W. Morris, a former student in aeronautical engineering at New York University, is now connected with the Alexander Aircraft Co., of Colorado Springs, Colo., in the capacity of aeronautical engineer.

G. Phillips is now serving Lubrication Devices, Inc., at Battle Creek, Mich., as experimental engineer. He previously studied at the University of Wisconsin.

C. F. Raisch has relinquished his position as designing engineer with the Bijur Lubricating Corp., in New York City,

Personal Notes of the Members
Concluded

to join the Alemite Mfg. Corp., of Chicago, for which he will act in a similar capacity in the experimental department.

Frank M. Say, until lately associated with the Universal Airline Systems, Inc., of Chicago, has entered upon his new duties as hangar manager for the Central Air Terminal Co., also of Chicago.

W. B. Small is now proprietor of the B. K. Brake Service Garage, in Los Angeles. He was formerly superintendent of design for the Lang Transportation Co., also of Los Angeles.

A. F. Stamm, formerly engine designer for the Lycoming Mfg. Co., at Williamsport, Pa., is now identified with the engineering department of the International Harvester Co. of America, at Springfield, Ohio.

Announcement was recently made of the appointment of **John Hardacre Stirk,** traffic manager of the Birmingham Cooperative Society, as Justice of the Peace for the city of Birmingham, England.

Foster E. Sturtevant has given up his position of mechanical engineer with the Bijur Lubricating Corp., of New York City, and joined the Whitney Mfg. Co., of Hartford, Conn., in the capacity of sales engineer.

R. B. Templeman has severed his connection as body engineer for the Edward G. Budd Mfg. Co., of Detroit, and is now acting in a similar capacity for the Stutz Motor Car Co., in Indianapolis.

H. H. Timian recently became identified with the commercial engineering department of the Harrison Radiator Corp., in Lockport, N. Y. Prior to establishing this connection Mr. Timian acted as research engineer for the Wheeler-Schebler Carburetor Co., of Indianapolis.

Walter Van Guilder has been appointed manager of the New Appliance Division of the Edison Electric Appliance Co., in Chicago. He previously held the position of assistant chief engineer of the Stewart-Warner Speedometer Corp., also located in Chicago.

Hiram Walker has severed his connection as consulting engineer for the Studebaker Corp. to become affiliated with the General Motors Export Co., in Detroit. Mr. Walker's new work will be in connection with special engineering research.

Herbert C. Walters recently assumed the post of chief engineer of the Delco Aviation Corp., in Dayton, Ohio. His previous connection was as designer for the Delco Products Corp., of the same city.

T. Ellwood Webster, formerly vice-president of the Ceroron Co., Bridgeport, Conn., is now associated with Cassatt & Co., investment bankers and members of the New York and Philadelphia Stock Exchanges.

Walter R. Westphal has left the Jordan Motor Car Co., of Cleveland, to join the experimental engineering department of the Stutz Motor Car Co., at Indianapolis.

Charles A. Winslow, a former consulting engineer for the Sheet Steel Products Co., of Michigan City, Ind., has been engaged as service executive by the Hercules Motors Corp., in Canton, Ohio.

S. J. Zand was recently appointed aeronautical engineer by the Taylor Instrument Companies, located at Rochester, N. Y. His previous connection was with the Ford Motor Co., at Dearborn, Mich., as aeronautical engineer.

George A. Zink is now acting as junior aeronautical engineer in the service of the Airplane Branch of the Materiel Division at Wright Field, Dayton, Ohio. Prior to entering upon his new duties, Mr. Zink was a student at Purdue University.

J. G. Zummach has tendered his resignation as vice-president and general manager of the Husky Corp., of Kenosha, Wis., and has disposed of his holdings in that company. His future plans have **not** been announced.